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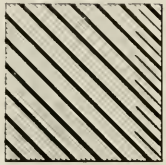
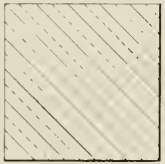
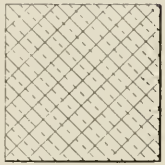


Nickel Steel Harveyed

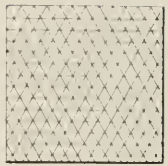


Brass or Composition



Copper

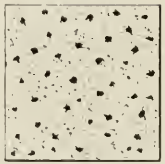
Lead or Babbitt



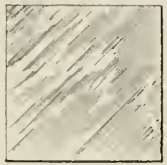
Zinc

Aluminium

Vulcanite

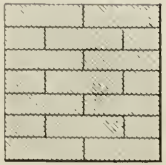


Leather or Sum



Glass

Wood



Brick

Stone

Cement

Earth

MARINE ENGINES:

PROBLEMS, NOTES AND SKETCHES.

ADDITIONAL TO THE TEXT-BOOK USED IN THE INSTRUCTION
OF NAVAL CADETS OF THE SECOND CLASS,
UNITED STATES NAVAL ACADEMY.

SECOND EDITION.

DEPARTMENT OF STEAM ENGINEERING,
U. S. NAVAL ACADEMY,
ANNAPOLIS, MD.
1899.

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PREFACE.

The following Problems, Notes and Sketches have been prepared for use in the instruction of the naval cadets of the second class.

The arrangement of the subjects treated follows that of the text-book on Marine Engines, in order that the books may be used conjointly.

The book is an outcome of a quantity of type-written matter which was prepared originally by Passed Assistant Engineers W. F. Worthington and John L. Gow, U. S. N., while attached to this school. With this has been incorporated much new matter, especial care having been taken to explain the uses and action of boiler and engine attachments and patented devices met with on board ship, in order that the cadet may obtain a thorough knowledge of the details of marine machinery, as well as a general understanding of the subject.

The "Arrangement of Machinery," and many of the devices mentioned, are those of the U. S. S. Bancroft, one of the Naval Academy practice ships, although not confined exclusively to that vessel.

Our thanks are due to Engineer-in-Chief Geo. W. Melville, U. S. N., Chief of the Bureau of Steam Engineering, Navy Department, by whose order many of the drawings for the book were made in that bureau.

We are indebted also to the following named firms and individuals for the loan of electrotypes of their specialties, and for unvarying courtesy in supplying all needful information, viz.:

American Ship Windlass Co., Ashcroft Manufacturing Co., Ashley Engineering Works, R. Beresford, Geo. F. Blake Manufacturing Co., A. & F. Brown, Chapman Valve Manufacturing Co., M. T. Davidson, Detroit Lubricator Co., D'Esté & Seeley Co., Goubert Manufacturing Co., L. Katzenstein & Co., Manning, Maxwell & Moore, Nason Manufacturing Co., Southwark Foundry and Machine Co., R. F. Sturtevant & Co., The Consolidated Safety Valve Co., The Eaton, Cole & Burnham Co.,

The Lunkenheimer Co., Williamson Bros., and Henry R. Worthington.

The labor of preparing the book has fallen upon the instructors in this department, Passed Assistant Engineers F. W. Bartlett and L. D. Miner, and Assistant Engineers H. W. Jones and H. O. Stickney, U. S. N.; to Mr. Jones, however, is due the credit for the greater part of the work.

C. W. Rae,
Chief Engineer, U. S. N., Head of Department of Steam Engineering.

U. S. Naval Academy,
Annapolis, Md., *Feb.* 1, 1895.

PREFACE TO SECOND EDITION.

The first edition of this work having been exhausted, the present edition has been prepared to correspond with the present text-book, "The Marine Steam Engine," by R. Sennett and H. J. Oram, which contains considerable matter that was in the first edition, and therefore can now be omitted. The removal of the "*Bancroft*" from this Station also allows the omission of all reference to the machinery of that vessel.

Brief notes have been added on steam turbines and liquid fuel; also, some directions about care and management of machinery afloat.

The notes on the Zeuner Diagram have been re-written and the notes on the Steam Turbine compiled by P. A. Engineer U. T. Holmes, U. S. N. The other additional matter has been compiled from notes used in the instruction of cadets in this department.

The matter and problems in this edition are arranged to correspond with the arrangement of similar subjects in Sennett and Oram.

GEO. H. KEARNY,
Chief Engineer, U. S. N., Head of Department of Steam Engineering.

U. S. NAVAL ACADEMY, *November*, 1898.

MARINE ENGINES.

ART. 1.—(P. 28, S. & O.)

To find the total heat necessary to evaporate one pound of water from a temperature of 32° to steam of t°, we have

$$H = 966 - .7 \times (t° - 212°) + (t° - 32°),$$

or, reducing the expression,

$$H = 1082 + .3t°.$$

If, however, we start the evaporation with feed water of a greater temperature than 32°, or rather with a temperature differing from 32°, we have already in the water (calling the new temperature of the feed $t_f°$) $(t_f° - 32°)$ of heat units which need not be supplied by the fuel.

Therefore this amount of heat can be subtracted from that necessary to evaporate the one pound of water to steam at the temperature t° from feed of 32° as an origin, as found by the above formula.

Calling the number of heat units already in the water H_f, taking 32° F. as the origin,

$$H_f = (t_f° - 32°),$$

and the heat to be supplied by the fuel

$$H - H_f = 1082 + .3t° - (t_f° - 32°).$$

PROBLEMS ON CHAPTERS III. AND IV., S. & O.

1. It has been determined by experiment that the ratio of the volumes of air, under the same pressure at temperatures 32° F. and 212° F., is 1 : 1.3654. Assuming that air is a perfect gas, *i. e.* follows the law $\frac{PV}{T} =$ a constant, find the absolute zero in degrees Fahrenheit.

2. Find the total, latent, and sensible heat of steam of temperature 300°.

3. Prove, by means of atomic weights, that 12 pounds of air are, theoretically, necessary for the complete combustion of one pound of carbon. Assume the composition of air to be 7 parts of N and 2 parts of O.

4. Similarly find the number of pounds of air necessary for the complete combustion of 1 pound of H. *Ans.* 36 pounds.

5. Explain how the formula for total heat of combustion is derived.

6. Find the total heat of combustion and the number of pounds of air necessary for the complete combustion of one pound of coal. The analysis of the coal is C = 90 per cent., H = 8 per cent., and O = 1.2 per cent.

Ans. 17921.71 B. T. U., 13.626 pounds of air.

7. How many pounds of water would a pound of pure carbon evaporate, theoretically, if all the heat of combustion of the carbon could be utilized, the water being at the boiling point under atmospheric pressure and the pressure of the resulting steam being also atmospheric? In other words, the evaporation being "from and at 212° F." *Ans.* 15.01 pounds.

8. How many pounds of water would the coal of question 6 theoretically evaporate from and at 212° F.? In other words, what is the "evaporative power" of such coal?

Ans. 18.55 pounds.

9. How many pounds of water would the coal of question 6 theoretically evaporate if the feed water be at a temperature of 80° F., and the resulting steam be at a pressure of 201 pounds absolute, and have a temperature of 228° F.?

Ans. 16.24 pounds.

10. How many heat units are equivalent to 1 I. H. P.?

Ans. 42.75 B. T. U.

11. Suppose that all the heat of combustion of pure carbon were available for useful work, how many pounds per I. H. P. per hour would be needed? *Ans.* .176 pounds.

12. The best results from modern engines show that 1.5 pounds of coal per I. H. P. per hour are needed. Comparing

this result with that obtained from the combustion of pure carbon, what is the efficiency of the modern engine and boiler?

Ans. 11 per cent.

13. A boiler uses the coal of question 6, and is found to evaporate 8 pounds of water per pound of coal burned. The water fed to the boiler has a temperature of 80° F. and the steam that is generated has a temperature of 228° F. What is the efficiency of the boiler? *Ans.* 49.7 per cent.

14. Assuming that a boiler has an efficiency of 65 per cent., burns 1000 pounds of coal per hour, and is fed with water having a temperature of 75° F., what is the total weight of water evaporated per hour to steam having a temperature of 300° F.? An analysis of the coal gives C = 91.5 per cent., H = 3.5 per cent., and O = 2.6 per cent. The ash may be neglected.

Ans. 8772 pounds.

15. The following is a partial record of the test of a certain boiler for efficiency: Temperature of feed, 80° F.; temperature of steam, 300° F.; number pounds of feed water used, 8000; number pounds of coal used, 1000. The feed water was kept at a constant level in the gauge glass and an analysis of the coal gave its composition as follows: Carbon = 90 per cent., hydrogen = 8 per cent., and oxygen = 1.2 per cent. What was the efficiency found to be? The test lasted one hour?

Ans. 50.18 per cent.

16. The temperature of the air being 100° F., what should be the temperature of the gases discharged from the smoke pipe in order that the draught shall be best? *Ans.* 707.75°.

17. A boiler is burning its maximum amount of fuel with natural draught, and it is found that the temperature of the gases discharged from the funnel is 600° F. What is the temperature of the air at the time? *Ans.* 48.3°.

18. How does cannel coal compare with pure carbon as a fuel, the composition of the coal being C = 84 per cent., H = 5.6 per cent., and O = 8 per cent.? Compare the amounts of air necessary to burn the two fuels.

Ans. 4 per ct. better as a fuel, and requires 2 per ct. less air.

19. The analysis of a coal gives C = .915, H = .035, O = .026. (*a*) How much air per pound will be required to burn it?

(*b*) How much water will one pound evaporate, theoretically, from a temperature of 120° F. to steam of 180 pounds pressure, the temperature of steam of this pressure being 373° F.? (*c*) If one pound of this fuel, when used in another boiler, evaporated eight pounds of water, what would be the efficiency of this boiler?

Ans. (*a*) 12.123 pounds of air;
(*b*) 13.77 pounds of water;
(*c*) efficiency, 58 per cent.

20. Mineral oil is by analysis .84 C, .16 H. Assuming that pure carbon represents a fair sample of good coal, how will its evaporative power compare with that of the mineral oil?

Ans. The coal has 65 per ct. the evaporative power of the oil.

21. A ton of coal requires 45 cubic feet of bunker space to stow it, and the specific gravity of mineral oil is .88. Assuming the average thermal value of the coal to be equal to that of pure carbon, how much cargo space could be saved if oil tanks were fitted in a vessel which has a bunker capacity of 1000 tons?

Ans. 40 per cent.

22. The analysis of peat, as given by Rankine, is carbon, 58 per cent.; hydrogen, 6 per cent.; and oxygen, 31 per cent. Compare the evaporative power of peat with that of pure carbon and find how much air is required to burn one pound of the peat.

Ans. As .67095 : 1.
7.725 pounds of air.

23. A boiler using peat for fuel evaporates 1 ton of water with 4.5 tons of peat. The feed water is kept at 75° F., and the pressure of the steam is kept constant at 25 pounds absolute. The temperature of the steam is 240° F. What is the efficiency of the boiler? *Ans.* 2.6 per cent.

24. A boiler is tested for 24 hours and during that time burns 235 pounds of coal. The feed has a temperature of 100° F. and 30.4 cubic feet of water are evaporated to steam having a temperature of 300° F.

The composition of the coal is 80 per cent. carbon, 10 per cent. hydrogen, and 6 per cent. oxygen, what was the result of the test as to efficiency? *Ans.* 51 per cent.

Calculation of Temperature of Furnace.

In the 12 pounds of air which are theoretically necessary for the complete combustion of one pound of carbon, there are $12 \times \frac{7}{9} = 9.333 +$ pounds of N. Burn the 1 pound of carbon with 12 pounds of air, to CO_2 and N, and the result is as follows:

			Heat Units Expended.
N	9.333 +,	specific heat .244;	$9.333 \times .244 = 2.2765$
CO_2	3.666	" " .217;	$3.666 \times .217 = .7942$
	13.000 of mixed gases.....		3.0707

Consequently the heat units required to raise the temperature of the gases 1° F. are 3.0707, and the elevation in temperature of the gases above that of the outside air is $\frac{14500}{3.0707} = 4723°$ F.

25. By the method given above, find the temperature of combustion when the air supply is just sufficient to burn one pound of carbon to carbonic oxide, the specific heat of CO being .245, and the value in thermal units of one pound of carbon so burned being 4400.

Ans. 2573° F. above the temperature of the air.

26. Find the temperature of combustion and the number of pounds of air necessary for the complete combustion of 1 pound of mineral oil, its composition being 84 per cent. carbon and 16 per cent. hydrogen. Specific heat of CO_2 is .217, of N is .245, of O is .218, of air is .238, of CO is .245, and of steam gas is .475.

Ans. 5073° F. above the temperature of the air.
15.84 pounds of air necessary.

27. Find the temperature of combustion caused by burning one pound of mineral oil with 25 pounds of air having a temperature of 90° F. *Ans.* 3445° F., about.

28. Find the number of pounds of air theoretically necessary for the complete combustion of one pound of bituminous coal, the analysis of the coal being 90 per cent. C, 4 per cent. H, and 2 per cent. O. The temperature of the air being 80° F. What will be the temperature of the furnace? Specific heat of ash = .20.

Ans. 12.15 pounds of air.
4868° F., temperature of furnace.

HEAT AVAILABLE FOR STEAM GENERATION.

Art. 2.—(P. 39, S. & O.)

Neglecting the heat lost by radiation from the ashpit and furnace front, it being a very small quantity as compared with that carried off by the chimney gases, the amount of the latter can be calculated if the temperature of the chimney gases be known; then the difference between the total amount of heat generated by the combustion of the fuel and the amount carried off by the discharged gases is a close approximation to the total amount of heat available for steam generation.

Suppose that the combustion of 1 pound of carbon generates 14,500 heat units when burned with 15 pounds of air, and that the temperature of the escaping gases is 600° F. The products of combustion will be 3.666 pounds of CO_2, .666 pounds of O, and 11.666 pounds of N.

To find the quantity of heat necessary to raise the products of combustion 1° F.:

Number of heat units carried off by the	CO_2	$= 3.666 \times .217$ (specific heat)	$=$	.7957
" " " " " " "	O	$= .666 \times .218$ "	$=$	.1453
" " " " " " "	N	$= 11.666 \times .244$ "	$=$	2.8467
" " " " " " "		16.0 lbs. mixed gases	$=$	3.7877

Since 3.7877 heat units are expended in raising the mixed gases 1° F., this quantity must be multiplied by the elevation in temperature of the gases.

Supposing the temperature of the air to be 50° F., the temperature of the gases has been raised from 50° F. to 600° F. during the process of combustion, or the elevation of temperature $= 600° - 50° = 550°$, therefore,

Heat units carried off by the chimney gases in this case

$$= 3.7877 \times 550 = 2083.$$

Heat units available for steam generation

$$= 14500 - 2083 = 12417.$$

Problems.

29. Assuming the thermal value of pure carbon to be 14500, find the heat available for steam generation when one pound of carbon is burned with 25 pounds of air, the temperature of the

supplied air being 80° F., and that of the escaping products of combustion being 600° F. *Ans.* 11281.2 B. T. U. available.

30. How many pounds of coal will be required to evaporate 450 pounds of water to steam having a temperature of 300° F.? The feed is 70° F.

The coal is composed of 88 per cent. carbon, 4 per cent. hydrogen, 6 per cent. oxygen, and 2 per cent. ash, and is burned with 24 pounds of air per pound of coal. The temperature of the air is 70° F. and of the escaping gases 570° F. Specific heat of ash about .200. *Ans.* 43.4 pounds of coal.

31. A boiler having the most favorable temperature of escaping gases is supplied with twice the amount of air theoretically necessary for complete combustion of the fuel.

The temperature of the supplied air is 80° F.

One pound of fuel, of the same composition as that of the preceding problem, evaporates 10 pounds of water, from a temperature of feed of 75° F., to steam of 240° F. Find the efficiency of the boiler, and the efficiency of its heating surface.

Specific heats of the products of combustion are as follows:—

Ash = .200 (about). O = .218 Air = .238 Steam gas = 475
CO_2 = .217 N = .244 CO = .245

Ans. Boiler efficiency = 75 per cent.
Heating surface efficiency = 98.2 per cent.

32. Using the coal of problem 30, it is required to find the number of pounds of water evaporated by one pound of the coal, the conditions being as follows:

Temperature of the feed water = 130° F.
" " steam, = 373° F.
Efficiency of the boiler, = 60 per cent.

Supposing that the temperature of the escaping gases is that most favorable for maximum combustion; find the efficiency of the heating surface of the boiler under the following conditions:

Number of pounds of air furnished per pound of fuel burned, ... = 12.
Temperature of supplied air, ... = 80° F.

Ans. 8.09 pounds of water per pound of coal.
Efficiency is 68.5 per cent.

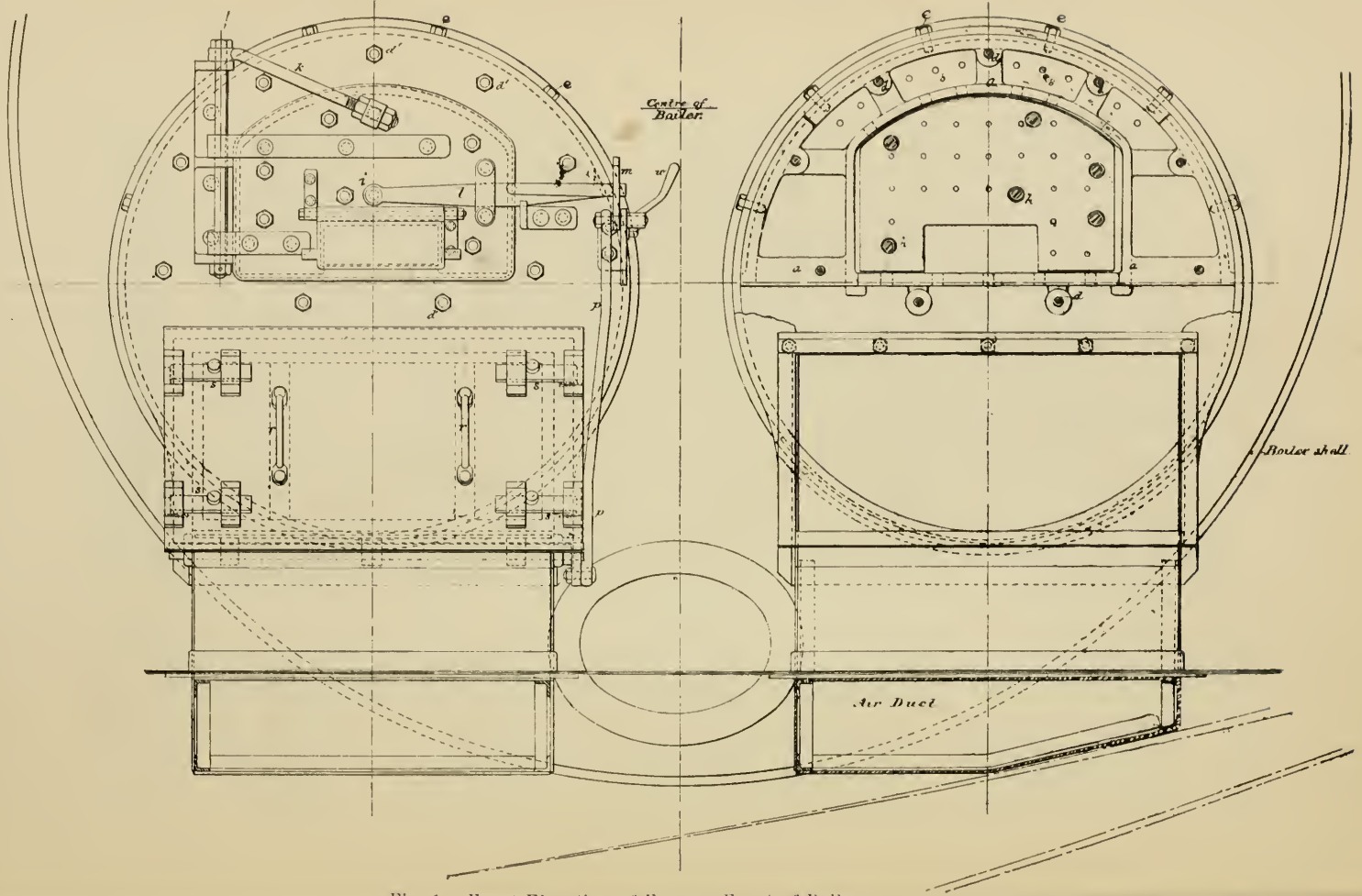


Fig. 1.—Front Elevation of Furnace Front of Boiler.

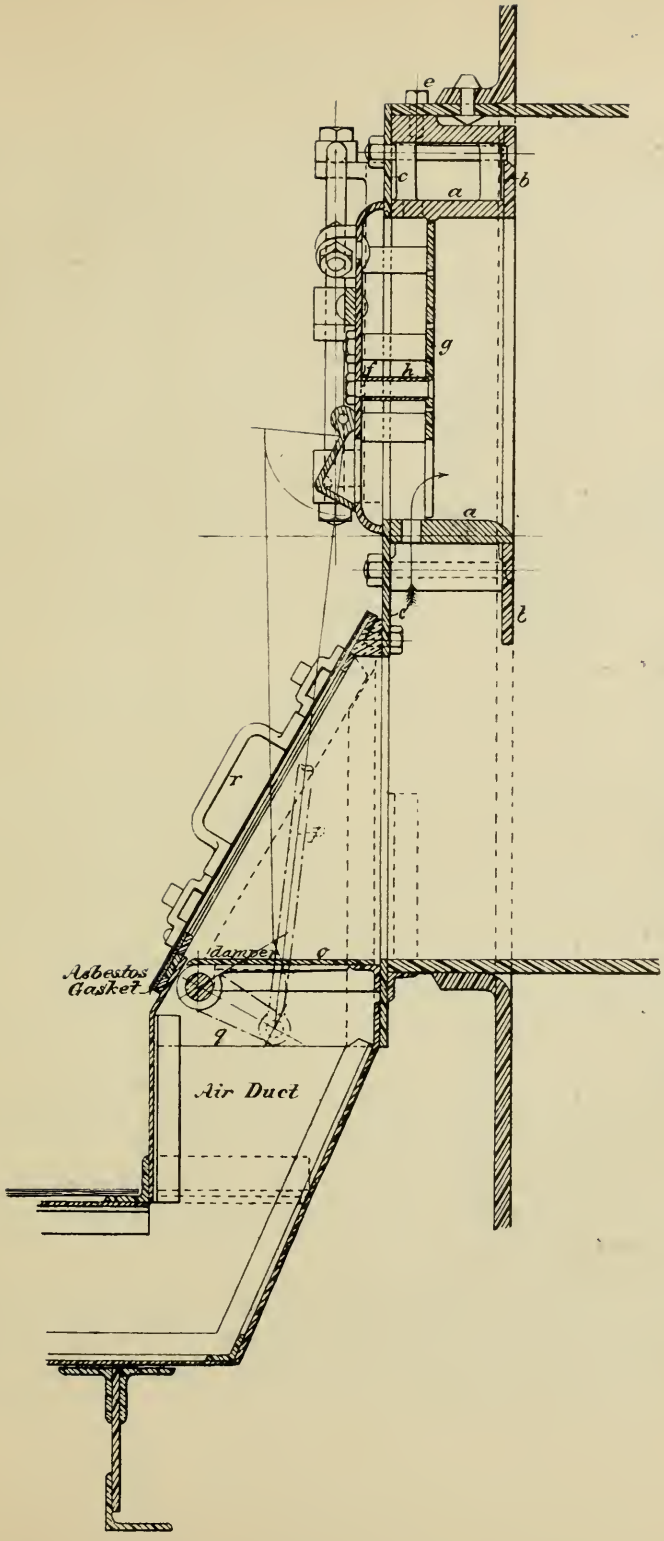


Fig. 2.—Vertical Longitudinal Section of Furnace Front of Boiler.

Art. 3.—(Chap. IV., S. & O.)

Figs. 1, 2, 3 and 4 show the arrangement of furnaces and ash-pits where forced draught is used with "closed ashpits."

The furnace front is built upon a semicircular ribbed cast iron frame, upon which suitable lugs are cast through which bolts may be passed for securing the covering plates, and in which various passage-ways are cast, through which the entering air may freely circulate about any portion of the frame.

The inner side of the frame, except the space occupied by the door, is covered with a perforated plate of steel, while the outside is covered with a solid plate which is bolted to the frame and the inner plate. This outer plate is carried down below the frame-work, and to it is bolted an inclined rectangular structure upon which an airtight door may be secured by the bolts *s*, and the ash-pit, or bottom half of the furnace, be thus shut off from the outer air. To the outer plate are secured lugs for the hinges and latch of the furnace door.

The furnace door is built up of an outer sheet of steel, its edge flanged so that it will fit tightly against the furnace front; and to this outer sheet is bolted an inner perforated sheet of such a size and shape that it will easily enter the opening in the casting as the door is swung to and fro. This inner sheet is secured by long bolts, which run through a piece of pipe, this pipe, with the bolt, serving to hold the liner rigidly a distance of three or four inches from the outer plate, thus allowing the air to circulate between the inner and outer plates, the easily renewable liner and the non-conducting air protecting the door from destruction and partially preventing radiation.

The latch and hinges are made fast to the door and the rod *k* is added to prevent the door from sagging on its hinges.

In the bottom of the outer and inner door-plates an opening is cut, and this opening is closed on the outer door by means of a plate swinging on horizontal hinges and kept shut by gravity. Through this opening a bar can be run and the clinkers can be lifted from the grates, or, technically speaking, the fires can be *sliced* with the *slice bar*.

In this method the furnace door and ashpit are tightly closed, and fans, rotating at high speed, compress air to a pressure of a small fraction of a pound per square inch, and force it through channel-ways or air ducts to the ashpit. These channel-ways

may be led across the front of the boiler, where the air is partially heated, and down to the ashpits, where it is discharged; or they may be led to the floor plates of the fire-room and under these to the ashpit as before.

The amount of air supplied can be regulated by varying the speed of the blowers, and it can also be controlled by a damper placed in the duct.

The ashpit is closed by a rectangular door fitted to make an airtight joint, and held in place by bolts, *s*, *s*, as shown in Fig. 1.

Fig. 3 shows the method of making the joint of this door so that it may be tight enough to prevent the escape of the air under its light pressure.

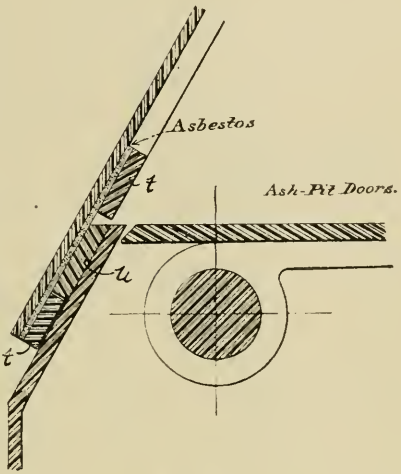


Fig. 3.—Method of Packing Ashpit Door.

To the inner side of the steel plate are fastened, by small screws, two light rectangular steel frames, *t*, *t*, one slightly larger than the other. These frames serve to form a channelway in which the edge of the ashpit box *u* just fits and prevent the door frame sliding down when in place. They also hold in place strips of asbestos sheeting, this last forming an elastic noncombustible packing which effectually seals the joint when the bolts are shot in place.

To the right of the door is shown a section of the damper spindle with a sectional portion of the damper attached.

With the blowers running and all the furnace doors and ashpit doors closed the pressure of the air and hot gases in the furnaces nearly equals that of the air in the ducts, and should a furnace door be suddenly opened, without first shutting off the damper of the air duct to the ashpit of that furnace, the hot gases would rush from the furnace through its door into the fire-room. Many serious accidents have happened in this way, and it is to save the firemen from the results of his own thoughtlessness that the mechanism shown in Fig. 4 has been added to the doors of many

furnaces in which combustion is aided by the *Closed Ashpit System* of forced draught.

It will be seen that the mechanism consists of a handle *m* pivoted at one extremity to a slotted plate, bolted to the furnace front, and having a curved arm *x* in one with it on its upper edge, while on the lower edge is a lug fitted with a bolt which passes through the slotted plate. The bolt is fitted with a handled nut *w* (see Fig. 1), by means of which the handle can be clamped at any point of its travel along the slot. To the other extremity of the bolt is made fast a rod *p* (see Fig. 1), the other end of which is connected with a crank on the end of the damper spindle.

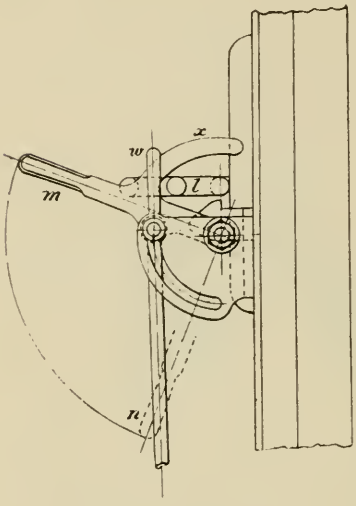


Fig. 4.—Side Elevation of Furnace Door Locking Device.

In the position of the handle shown, the curved arm *x* is over the door latch *l* (also see Fig. 2), and until *m* be swung down carrying *x* with it, the door latch *l* cannot be raised from its hook, and consequently the door cannot be opened.

Should the fireman wish to open the door, he must unclamp and push down the lever *m*, and must push it down so far that the end of *x* will clear the latch *l*, and this will bring the handle *m* into the new position *n*. But when the handle *m* is shoved down, the rod *p* (see Fig. 1), is carried down too, and as it goes down it turns the crank on the damper spindle, and so closes the damper and shuts off the air. The position of the damper when closed is shown in Figs. 2 and 3.

It can now be seen that if the fireman wishes to open the door of the furnace, to do so he is forced to first close the damper, thus relieving the gases of the additional pressure, when he may raise the latch and open the door.

NOTES ON LIQUID FUEL.

Art. 4.—Chap. VI., S. & O.)

Liquid Fuel—Gives special facilities for the development and maintenance of intense heat, for the quick control of applied, steady heat, and for the rapid generation of steam. Liquid fuels, such as petroleum, petroleum residue, tar, and creosote-oil have a much higher calorific power than coal, because they contain a much larger quantity of hydrogen. Petroleum is a natural hydro carbon oil, having in its crude state a calorific power one and one-half times as great as that of coal. Petroleum oil is obtained by distillation from petroleum. Its calorific power is from two and one-half to three times that of coal. The best petroleum fuel oil has a specific gravity of 0.818. Its composition averages as follows: Carbon, 85.34; Hydrogen, 13.51; Oxygen and impurities, 1.15. It contains about three times as much hydrogen as is contained in good coal. The theoretical heating power of this fuel is 20,822 thermal units, and it has a theoretical evaporative power of $\frac{20822}{966} = 21.56$ lbs. of water, from and at 212° F. per lb. of oil. Its actual evaporative power in practice is from 15½ to 17 lbs. of water. Its flashing point is about 217° F. In a general way 104 gallons or 851 lbs. of this oil are equal to one ton of good coal in evaporative power. Petroleum fuel is burned in a furnace in the form of spray after having been pulverized or atomized by steam or compressed air or both. An ordinary furnace can be used for burning fuel oil, but a large quantity of smoke is formed and the heating surface becomes coated with a sticky non-conducting substance. Better results are obtained by lining the furnace with fire-brick when the high temperature prevents the cooling of the gases and the partial extinction of the flame. When the oil is sprayed into a furnace of this kind and a large quantity of air is supplied, practically complete combustion may be obtained with no soot.

Air Required.—The air required for the complete combustion of fuel oil is at least one-third greater than that required for coal of good quality. The minimum quantity of air that should be provided in practice is 22 lbs. of air per lb. of oil, but it is generally necessary to provide a larger amount than this to prevent smoke.

Comparison of Coal and Oil for Composition and Theoretical Evaporation.

	Spec. grav. at 32°.	C.	H.	O.	Heating power in thermal units.	Theor. evap. at 212° per lb. of fuel.
Penna. heavy crude oil....	.886	84.9	13.7	1.4	20736	21.48
Caucasian " "	.938	86.6	12.3	1.1	20138	20.85
Petroleum residue	.938	87.1	11.7	1.2	19832	20.53
Good English coal.....	1.380	80.0	5.0	8.0	14112	14.61

Boiler using Liquid Fuel.—As a boiler well equipped for the combustion of liquid fuel should produce no soot, the tube may be of small diameter and the heating surface may thus be increased from 33 per cent. to 50 per cent.

Petroleum Residue or Astaki.—This is the liquid fuel generally used and is the dead oil or residue left in the still after the crude oil has been refined. It makes an excellent fuel for boilers. The flashing point is about 212° F. The theoretical evaporation is 17.1 lbs. of water per lb. of fuel. The actual evaporative value is found to be 14 lbs. or 82 per cent. of the theoretical efficiency.

The Working of Oil Fuel Apparatus on Board Ship.

With petroleum fuel the regulation of the fires is very simple: the only thing of importance to be observed is to adjust the regulating valves of the pulverizers and the air doors of the furnaces in such a way as to get a brilliant white flame throughout the furnace, entirely free from reddish, bluish, or yellowish striæ, in order to ensure perfect combustion. Perfect combustion is necessary not only for the economy of fuel but also for preventing the formation of smoke or a second combustion taking place in the uptakes, which frequently happens. When the fires are well regulated the firemen have nothing to do except to watch the water level in the boilers and the level in the oil-feeding tank. One man can look after many boilers and a great saving in labor can be effected. Other advantages not to be disregarded are the great uniformity of fire and consequently of steaming; the easy regulation of the boilers; and the cleanliness that obtains in the fireroom, on account of the total absence of coal and ashes. As

the oil fuel is very dense, to make it more fluid, it is usual to heat it in the feeding tank with steam through a steam coil.

Heating the oil has also the advantage of improving combustion and diminishing the expenditure of steam in the pulverizer. To prevent sediment finding its way into the oil-feeder tank the latter is fitted with a strainer through which the oil pumped through the main reservoirs is made to pass. The oil reservoirs on board ship, which in men-of-war ought always to be built below the waterline, may be kept with the oil at a free level which falls as the oil is pumped out; or it may be kept full. In the latter case the reservoirs are put in direct communication at the bottom with the sea, and the oil is pumped out at the top as required. This arrangement has the advantage that the oil being kept steady and being taken from the top is freer from sediment, while the conditions of trim and stability of the ship are left unaltered. The water being heavier rests at the bottom and there is no danger of its mixing with the oil. Air-pipes are always fitted to the tops of the reservoirs for the free exit of gases and entrance of air. Whether kept full or at a free level the oil reservoirs are not dangerous because the naphtha refuse left as waste in the refining works after the illuminating oils and lubricating oils have been distilled has a very high burning point, which is above 200° C. Sometimes, however, a refuse with a high burning point may be mixed with another of a more volatile nature which has been left as waste after the illuminating oils only have been distilled; and sometimes crude petroleum itself, with all the volatile oil, is mixed with the refuse. In these cases of mixture there may be danger. It is, therefore, of the utmost importance that the oil fuel be tested, to ascertain that it is free from vapors and light oils, and that it has a high burning point, at least 130° C. before it is received on board.

Use of Coal and Oil Fuel Combined.—This is effected by working a coal fire on an ordinary grate and admitting the oil fuel through holes above the furnace door, leaving the door free for coal firing. When using the two fuels combined, care must be taken to allow air to enter in sufficient quantities inside the furnace above the fire-grate in order to insure perfect combustion. Failing this, combustion may take place in the smoke box and funnel. This is prevented by leaving the grate barely covered in front near the fire door. With the combined fuels in ordinary marine furnaces the flame is not so white as with liquid fuel alone,

burning inside a fire-brick chamber. The proportions of fuels used, one of oil fuel to five of coal, appear the most convenient to secure power combined with efficiency. When using the combined fuels it is necessary for perfect combustion to work the coal fire as regularly as possible, just as when using coal alone; but, in the former case, the rush of cold air through the furnace doors when firing is not so detrimental as with coal alone, the cold air always finding in the furnace above the grate a large quantity of hydrocarbon vapors with which it must mingle before reaching the tube plates. An important feature of the use of liquid fuel with coal lies in the readiness and ease with which the full power of the boilers can be obtained by a simple turn of a handle.

Experimental Data and Conclusions.

From experiments in the Italian navy the following are obtained: The heating power of petroleum refuse compared with that of coal is at least 1.44, reckoned from the weight of water evaporated per equal weight of fuel. It is found that when using both fuels the power obtained under the same conditions is increased ten per cent. over that obtained with coal alone, and that the calorific power of oil fuel used in this way is 1.55 times that of coal. The fuels used per I. H. P. are about 1.21 lbs. of coal and 0.31 lbs. of oil, making a total of 1.50 lbs. per I. H. P. burned together and about 1.71 lbs. of coal per I. H. P. used alone.

The conclusions arrived at in the Italian navy are as follows: 1. Petroleum refuse seems to be the marine fuel par excellence. 2. At present on account of the high price and the small quantity available, notwithstanding the many advantages that may be derived from it, petroleum refuse cannot be adopted for general use on board ship, at least in the mercantile navy. In war ships its military advantages may lead even now to its partial adoption. 3. The use of coal and oil fuel combined gives an easy and safe way of using the greater power of oil without dispensing with the coal arrangements. 4. For torpedo boats requiring small fuel carrying capacity and steaming short distances oil fuel can now be used to advantage.

The following are the objections to the use of liquid fuel in naval vessels: 1. Even with the utmost care a certain amount of volatile substance is sure to be mixed with the refuse burned and the intense heat of the upper parts of the fire-rooms in naval

vessels is a certain cause of danger; the fuel quickly developing the generation of gases which increase as combustion is forced. The accumulation of gases goes on continually and is invariably present in any existing space and is apt to explode whenever heat and air strike it. 2. Oil penetrates the riveted seams and rapidly deteriorates the rivets of the oil reservoirs and would have the same effect on the metal of the double bottoms (which would probably be used as the reservoirs) in naval ships. These could not be examined regularly as it takes a week or more with the strong blast of a fan to prepare a compartment for entrance. The examination would not be satisfactory as the surfaces are covered with thick deposit. 3. The odor has not yet been overcome and is very objectionable. 4. A special objection is due to the fact that the weight of water used in the form of steam for burning the fuel is from 8 to 13 per cent. of all the water evaporated, which would prevent the use of this fuel for seagoing ships where there is already such difficulty in keeping fresh water in the boilers.

WARD'S LAUNCH BOILER.

Art. 5.—(Chap. VIII., S. & O.)

Fig. 5 is the type known as *Ward's Launch Boiler*, and it is in use in a number of the launches in our navy. *F* is a drum of sheet steel with curved cast steel bottom head and having a large *hand-hole* in its top head. From the bottom quarter of this drum, curved, spaced tubes run down and join the lower annular drum *C*, which curves vertically at *G* to permit placing the door frame and door *G*. From the bottom of the upper or *steam drum F* are hanging tubes which are normal to the curved plate.

The grate bars are supported by lugs on *C* and a metal casing covers and supports the whole, and terminates in the stack.

The feed water is pumped into the drum *F* and falls inside the space around the plate *A*, from which it enters the upper ends of the vertical tubes, as shown by the arrow, falls to *C* and, rising, pours out of the upper end of the shorter vertical tubes and falls upon the curved plate.

The hanging tubes are seen to hold two smaller tubes, one projecting above the curved plate, the other below and into the hanging tube. The water from the bottom of the steam drum therefore runs into *b*, and, with its contained steam rises through *e*,

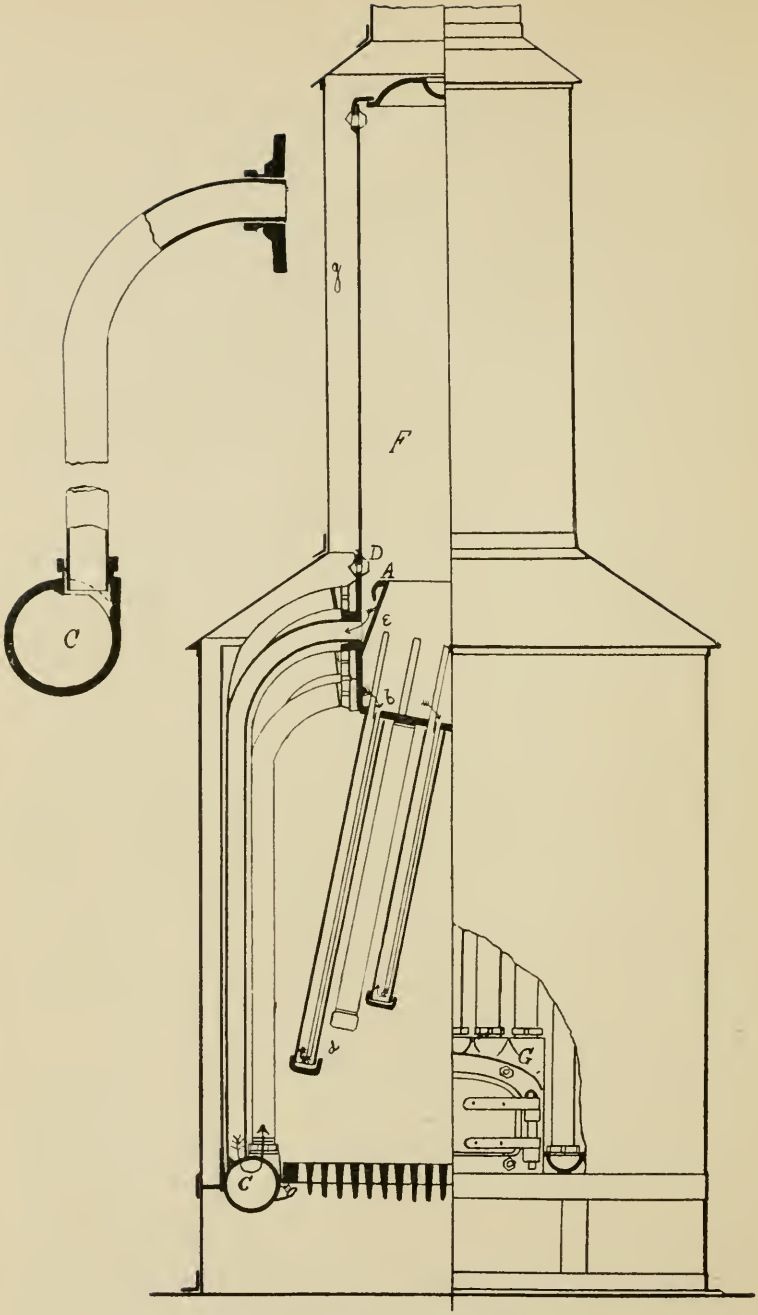


Fig. 5.—Ward's Launch Boiler

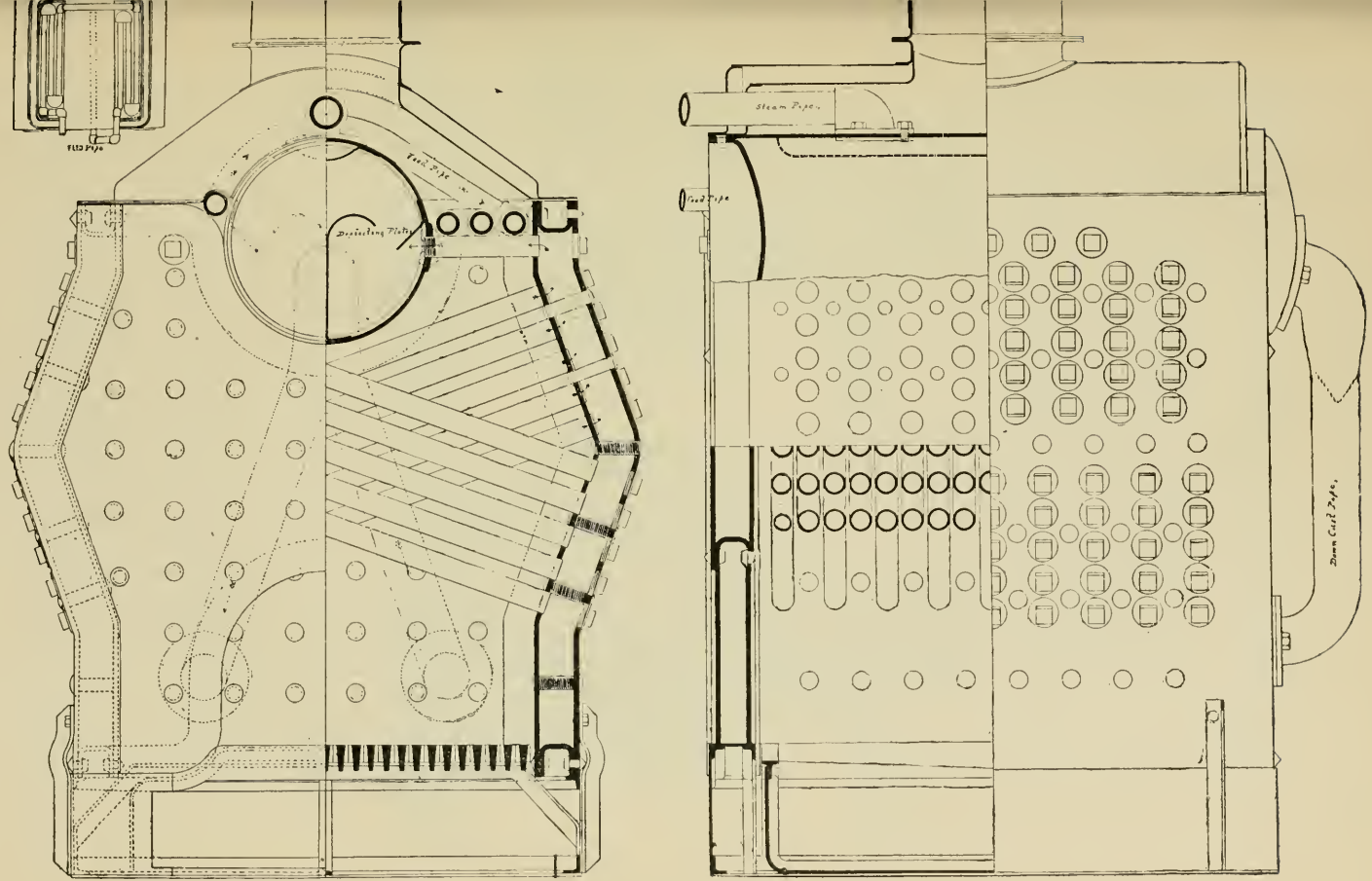


Fig. 6.—Towne's Launch Boiler

the steam further rising into *F*, from which it is drawn for use, while the entrained water descends again through *b* to be further evaporated.

The process then is to fill the space around *A* with water. Gravity causes it to descend in the vertical tube, and in its descent it is partly heated by the furnace gases which surround these tubes. It fills *C*, is further heated as it rises through the inner vertical tube and is discharged, as water and steam, into the lower part of the drum. The steam rises, while the remaining water falls, passes through *b* to the bottom of *d*, the hanging tube, and rises as already described. The circulation is thus seen to be automatic and the water must continue its circuit until it shall all have been evaporated, other water being meanwhile supplied to *A* to equal the amount evaporated and drawn off.

Towne's Launch Boiler.

Another type, also used in some of the steam launches, is *Towne's Boiler*, shown in Fig. 6.

This type combines a shell of small volume with the large tube surface and the upper, or steam, drum. The shell encloses the grates and the gases pass between the inclined tubes above the grate and pass out of the funnel above.

The feed water enters a pipe coiled along the steam drum, and the hot gases give up some of their heat to this pipe and the contained water, before the water is discharged into the lower part of the steam drum.

The feed, heated as explained, fills the lower part of the drum, runs into the *down-cast* pipes *C*, enters the lower part of the shell and, rising, fills the tubes to the level of the water in the drum. Heat being applied, the steam bubbles rise along the inclined tubes *D* and the shell, and collecting in the top of the shell are discharged through the tubes *B* against the deflecting plates *S*. The entrained water falls to the bottom of the drum, while the liberated steam is drawn off through the perforated plate *P* and the steam pipe *H*.

The feed continually entering, the circulation goes on continuously as explained.

Art. 6.—(P. 106, S. & O.)

The safety valve shown in Figs. 85 and 86 of Sennett & Oram is similar to those used in our navy except that the springs and

adjusting nuts are protected by a metal casing, and the valve is lifted by a lever acting on the top of the valve stem. Fig. 7 shows a valve and its sectional view. In the navy two or more valves are often fitted in the one casting, so as to get the required valve area without having too large a valve.

This valve has a seat of solid nickel (which does not corrode), beveled at an angle of 45°. The valve is fitted with Richardson's adjustable screw ring, by which the closing pressure can be altered without taking the valve apart: this is done by removing the small plug shown on the right of the sectional view and moving the ring by means of a pin, thus raising or lowering its upper edge.

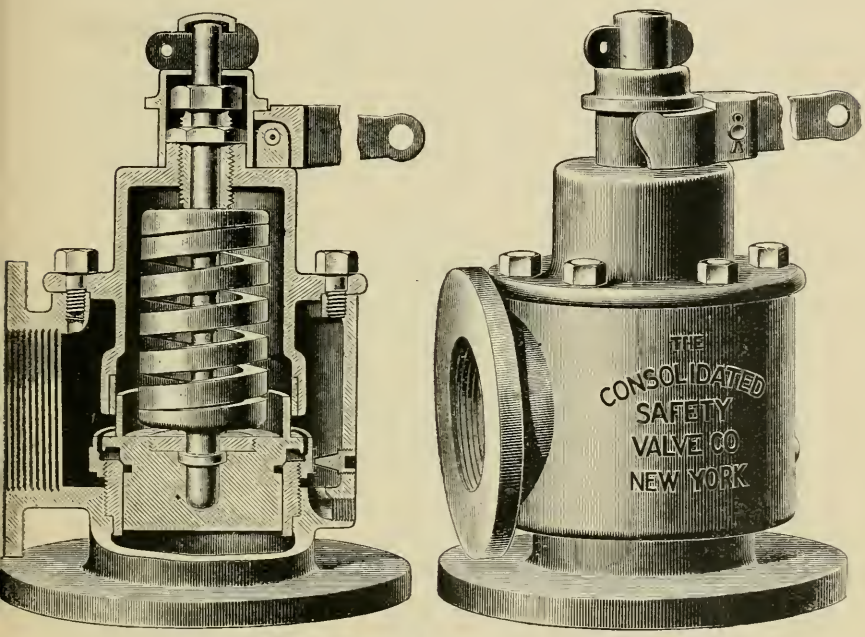


Fig. 7.

The valve is lifted by means of the lever acting on the loose casing over the nuts at the top of the valve stem, which lifts the valve by means of the key fitted through the valve stem. This key can be secured by a padlock through the hole shown in its end, thus preventing any tampering with the adjusting nuts after once set. The section of the valve itself, as shown, is through one of the cross guides fitted below the valve.

SENTINEL VALVE.

Art. 7.—(P. 109, S. & O.)

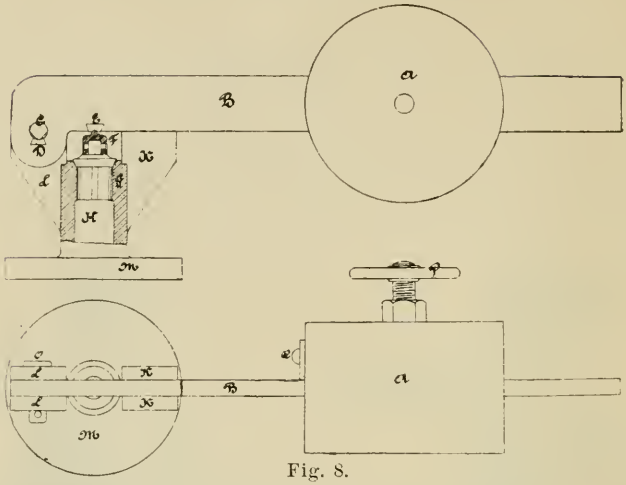


Fig. 8.

The *sentinel valve*, shown in Fig. 8, will be seen to be a small weighted lever safety valve, with a sliding weight *A*, which can be changed to any point on the lever *B* by the screw and hand wheel *P*.

The flange *M* is bolted to a pipe leading from the steam space, and the weight is so set as to exert a pressure, slightly below the working pressure of the boiler, upon the valve *f*. The valve will rise when this pressure is reached, and the steam hissing from the small opening into the fire-room will call the attention of the water-tender to the increase in pressure, and warn him to check it before the safety valves begin to blow. *K* and *L* are guides and supports; *E* and *D* are hardened steel bearing-plates.

THE LANE IMPROVEMENT.

Art. 8.—(P. 110, S. & O.)

This is an improvement on the Bourdon gauge, shown on p. 110 of the text-book. The closed tube is connected near its middle to the steam pipe, the two ends coming one above the other near the top of the gauge, and the sector which moves the index is connected to each end. This arrangement multiplies the motion and enables a stiffer spring to be used, thus increasing its durability and accuracy after long use. One of these gauges will be found in the model room.

Art. 9.—(P. 111, S. & O.)

It sometimes happens that the gauge glass breaks and steam and hot water are blown violently out into the fire-room until the valves at the top and bottom of the glass can be shut. As the gauges are usually just over the furnace doors, this accident is liable to cause some of the firemen to be scalded unless the valves can be made to close automatically.

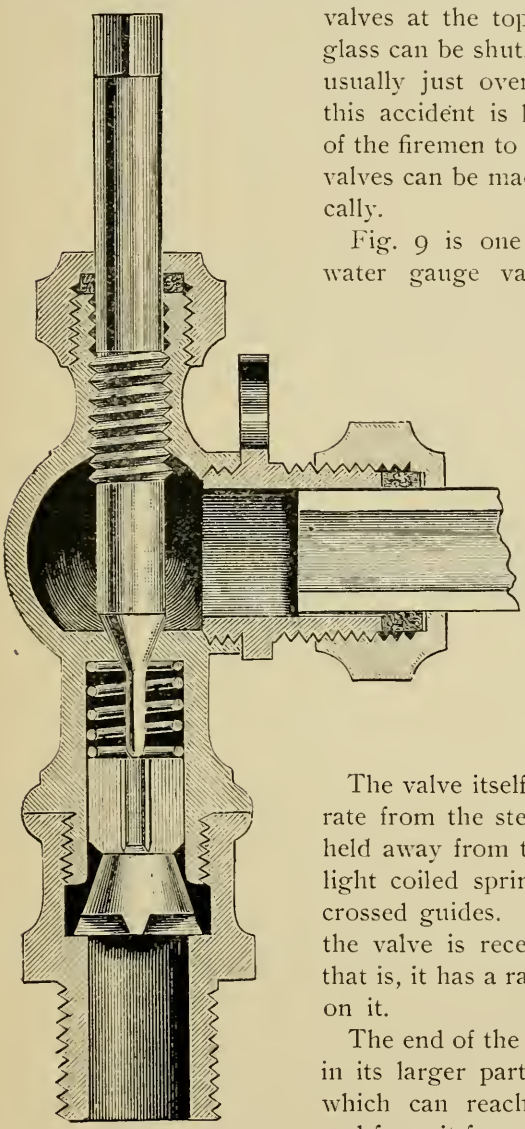


Fig. 9.—Keyser's Automatic Water Gauge Valve.

Fig. 9 is one of these automatic water gauge valves shown closed. The valve wheel is fitted to the square end of the stem and the glass is fitted as shown, the threaded end of one valve being fitted to the pipe to the steam space, the other to the pipe to water, the glass being vertical and the valve stems horizontal, instead of as shown in the figure.

The valve itself is conical and separate from the stem, and is ordinarily held away from the conical seat by a light coiled spring fitted against the crossed guides. The opposite end of the valve is recessed in four places; that is, it has a raised metal cross cast on it.

The end of the valve stem is conical in its larger part, and ends in a pin which can reach the separate valve and force it from its seat when closed. The conical part of the stem forms a

second valve fitting to a seat in the casting just back of the coiled spring. This valve is shown closed. If it be opened water or steam will flow by the larger and smaller valve into the gauge glass and will there be in equilibrium. Should the glass break there is a violent issue of steam or water, and the larger valve being carried along with it compresses the coil spring and seats itself, thus shutting off the flow automatically.

The smaller valve can then be safely closed, a new glass can be inserted, the small valve opened again and the steam and water readmitted to the glass.

ART. 10.—(P. 116, S. & O.)

An oily scum may collect upon the surface of the water in the boilers, and provision must be made to get rid of this by blowing it overboard. Fig. 10 shows the method employed. The

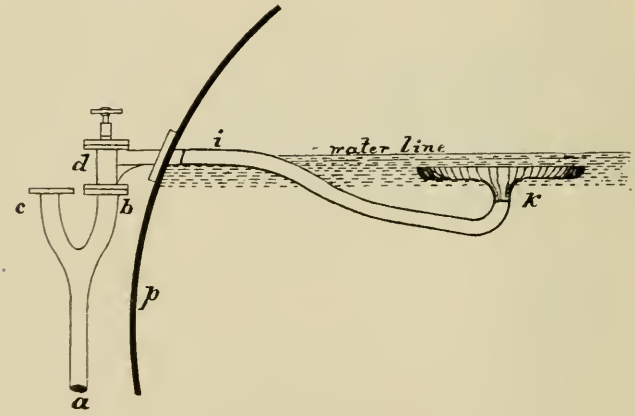


Fig. 10.—Surface Blow.

branch pipe *a* has *angle valves* fitted to each of the flanges *c* and *b*, and these valves are flanged and bolted to the shells of adjacent boilers. From each valve is led an interior pipe *i* which ends in a *scum-pan* just under the surface of the water near the centre of the boiler.

The scum-pan *k* is sometimes placed in an inverted position about four to six inches above the ordinary water level in the boiler.

Also, in place of the scum-pan, an open pipe or trough is

sometimes fitted just below the water level, extending around the inside of the boiler, near the shell.

When the valve *d* is opened, the pressure of the steam forces the water into the scum-pan and through the valves and piping overboard; the scum on the surface of the water is drawn to the place of discharge and, as the water becomes lower, it is gradually forced into the pipe and overboard also.

Art. 11.—(P. 117, S. & O.)

The *surface blow* is sometimes used, though it is best to use the *bottom blow*, to reduce the *saturation* of the water, this having been previously found by means of the salinometer shown in Fig. 11. The *globe valve a* is connected to a pipe leading from the water space of the boiler, and when it is opened, the water rushes up the pipe *b*, the end of which is closed by a solid cap *o*, and pours out through the small holes near its end. There is a channel *d* in the bottom of *c* which connects this chamber with *e*, in which are seen the *thermometer* and *salinometer* or *hydrometer*. The water rises quietly to the top of the overflow tube *f* through which the surplus amount escapes to the bilge.

The thermometer being in place, the water is turned on, and its temperature is allowed to rise to either 190°, 200°, or 210°, when the salinometer is put in and the scale corresponding to the temperature used is read on the stem. The salinometer is kept upright by the shot in its lower end, and the water having been previously quieted in the chamber *c*, allows a correct reading to be made.

The scale of the salinometer used in our navy is graduated to represent the number of pounds and quarter pounds of salt contained in thirty-two pounds of the mixture, and the lengths of the divisions of the scale are calculated as follows:

Let W = weight of 1 cu. in. of pure water.

$w = \frac{W}{32}$ = increase in weight of 1 cu. in. of water, due to the addition of $\frac{1}{32}$ of its weight of salt.

$\therefore W + wx = W\left(1 + \frac{x}{32}\right)$ = weight 1 cu. in. of water to which $\frac{x}{32}$ of its weight of salts have been added, or, in other words,

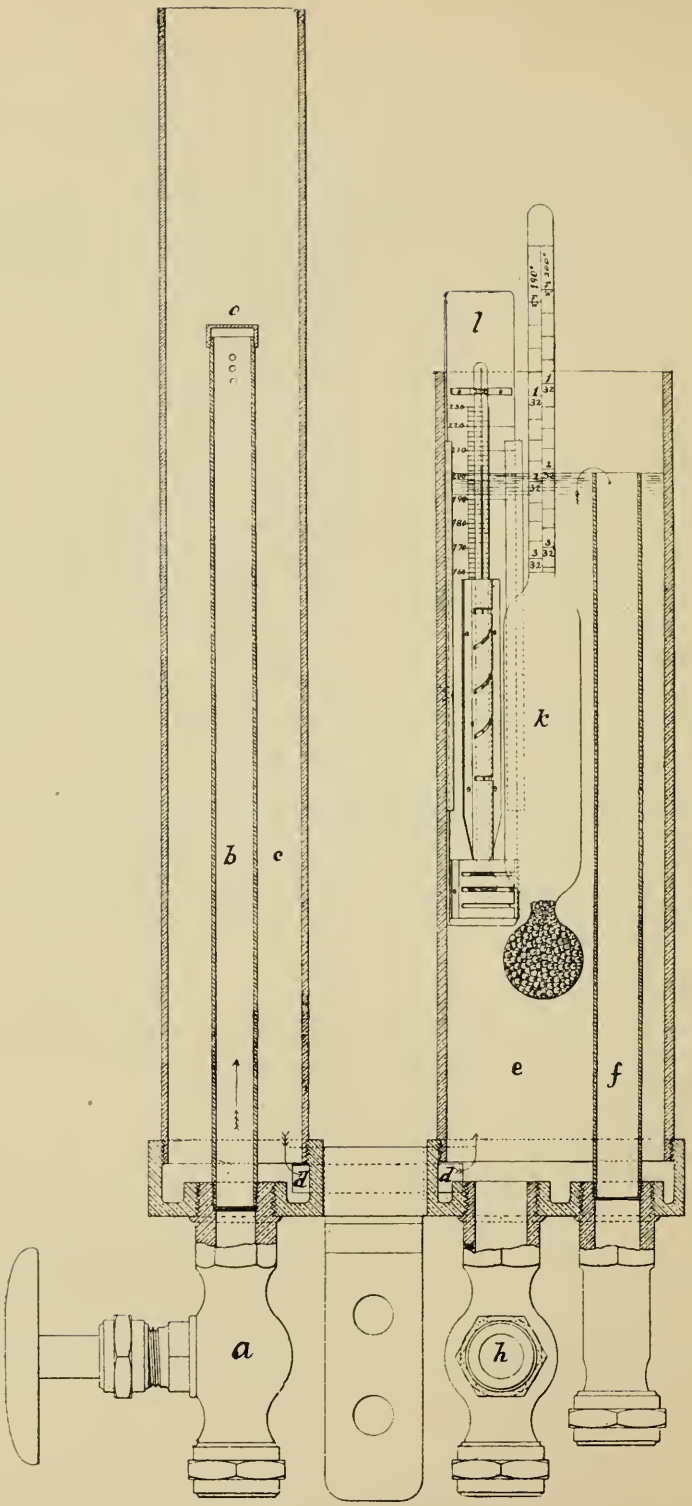


Fig. 11.—Salinometer.

the weight of 1 cu. in. of water from a boiler the density of whose contents by salinometer is $\frac{x}{32}$.

Let the stem of the hydrometer be of uniform size and have a cross section of a sq. in., and let V equal the volume in cu. ins. of the immersed portion of the salinometer when floating in pure water, then WV is the weight of the salinometer.

Let $y =$ the amount the hydrometer rises when floating in water whose density is $\frac{x}{32}$; its immersed volume will then be $(V - ay)$. This quantity, multiplied by the weight of 1 cu. in. of salt water of the density of $\frac{x}{32}$ will equal the weight of the salinometer; or $(V - ay)(W + wx) = VW$.

$$\therefore V - ay = \frac{VW}{(W + wx)}; \quad \text{or } y = \frac{V}{a}\left\{\frac{wx}{(W + wx)}\right\} = \frac{V}{a}\left(\frac{x}{32 + x}\right).$$

From this the different values of y can be calculated.

STOP VALVES.

Art. 12.—(P. 119, S. & O.)

Valves similar to the one shown in Fig. 12 have been extensively used in some of the later ships of our navy in both steam and water pipes. From its form it is called the *Gate Valve.*

Owing to the unobstructed passageway, when the valve is lifted, there is much less frictional resistance to the passage of steam or water than is offered by the crooked channel of the *globe valve* described above, and the *gate valve* has the further advantage of weighing less and being more compact than the *globe valve* of the same capacity.

The wedge form of valve and removable seat can be seen in the sectional view. By turning the threaded hand wheel, in Fig. 12, the stem and valve settle slowly into place and the *valve faces* are forced tightly against both *valve seats.*

In large *gate valves* the pressure may be so great that the valve can be raised only by applying great power to the hand wheel. To obviate this a smaller *by-pass valve,* shown on the elevation, is fitted to the chamber, and, when opened, the pressure on both *valve faces* is soon equalized and the main valve can be easily opened.

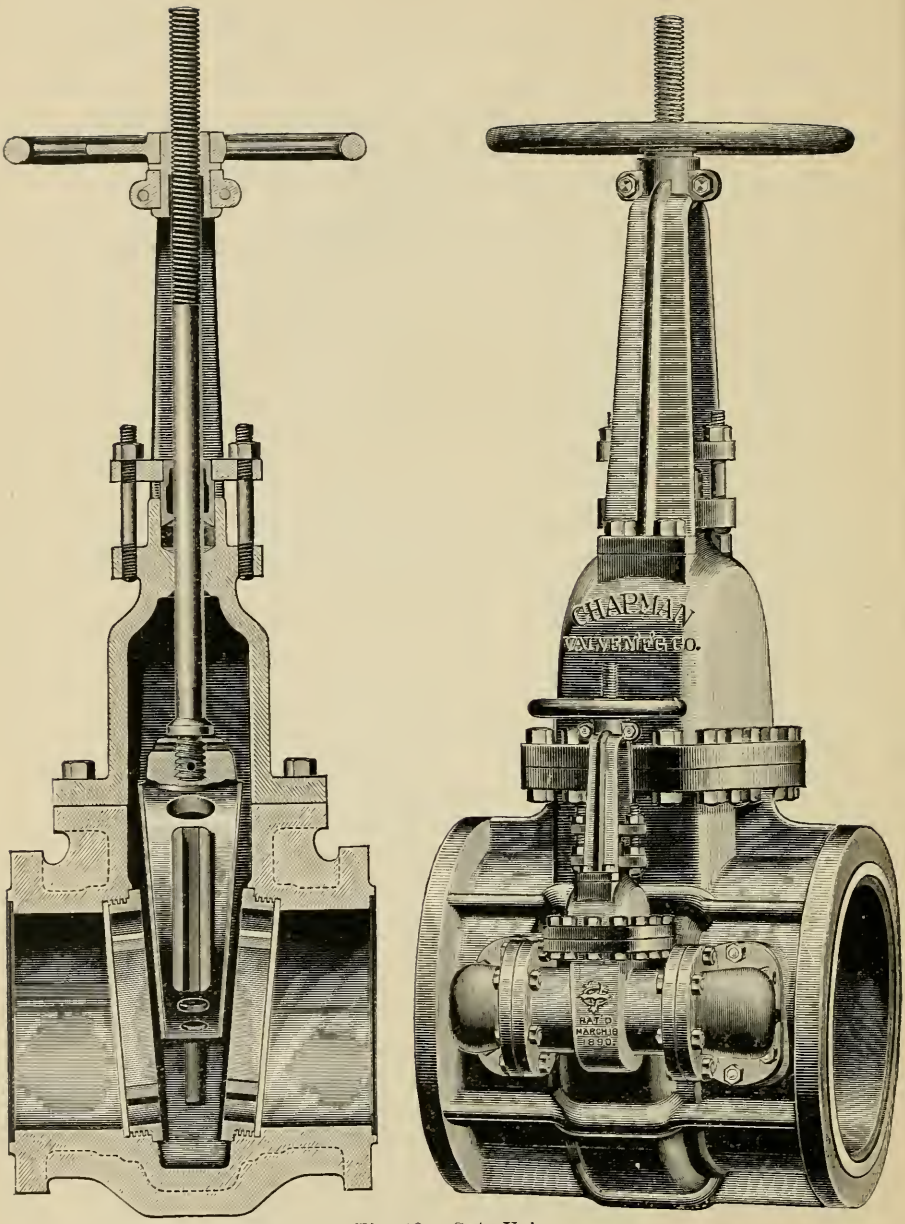


Fig. 12.—Gate Valve.

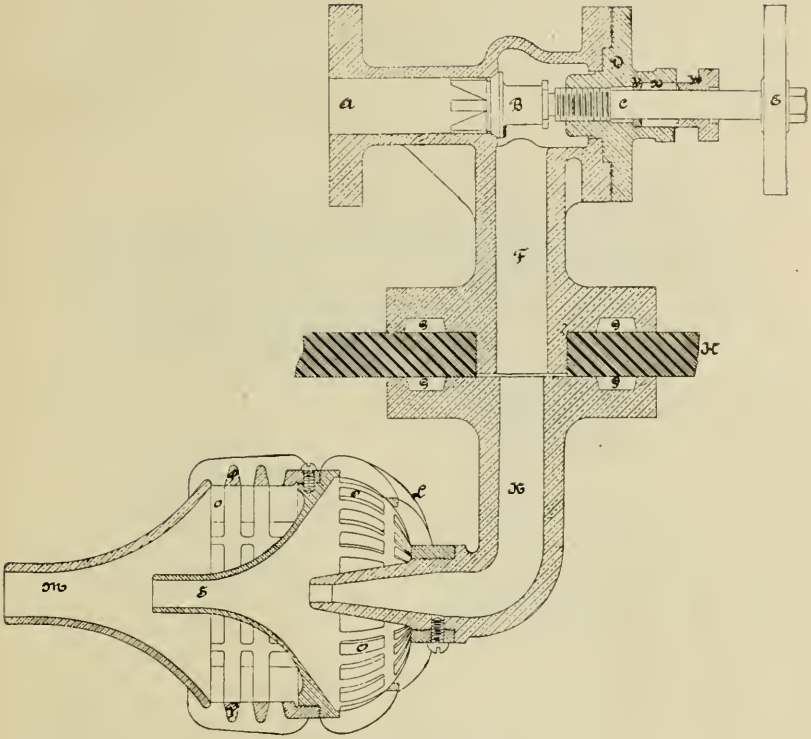


Fig. 13.—Hydrokineter.

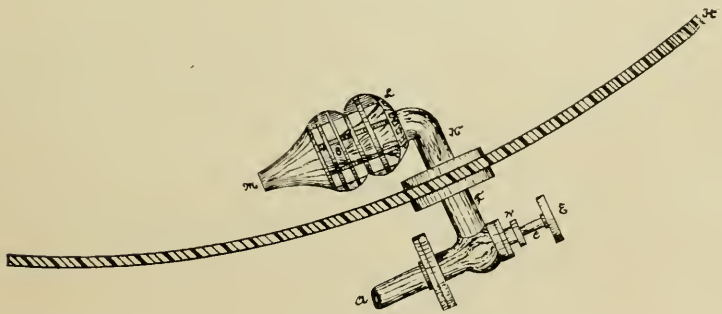


Fig. 14.

It may sometimes happen that it is inconvenient to have the stem rise with the valve, in which case a modification is used: the nut and valve are in one, and the threaded portion of the stem is shrouded when the valve is opened. The stem is prevented from rising by a collar turned on it and fitting in a recess in the valve bonnet. Models of small sizes of these valves, in section, are in the model room.

CIRCULATING APPARATUS.

Art. 13.—(P. 119, S. & O.)

Because of the enormous strains set up in a cylindrical boiler when one part is heated while the others remain cold, it is necessary that the water be made to circulate freely when steam is being raised, and thus be heated and so heat the boiler shell uniformly.

A method of accomplishing this result is shown in Figs. 13 and 14. Steam is admitted through the *hydrokineter* from some exterior source, and, as it rushes through the nozzles, draws the surrounding water in through the grating *o* surrounding the nozzles, discharging it forcibly from the nozzle *m*. This sets up local circulation, which in turn sets all the water in the boiler moving, so heating it uniformly.

They are started some hours before the fires are lighted in the furnaces and, as all the steam used in heating the water enters the boiler, the water level must be left low enough at the start to allow for the increase in amount due to the added steam.

Another plan, generally used, is to use one of the auxiliary feed pumps to pump water out of the bottom of the boiler and feed it back into the boiler through the regular feed check valve and distributing pipes while steam is being raised by means of the fires.

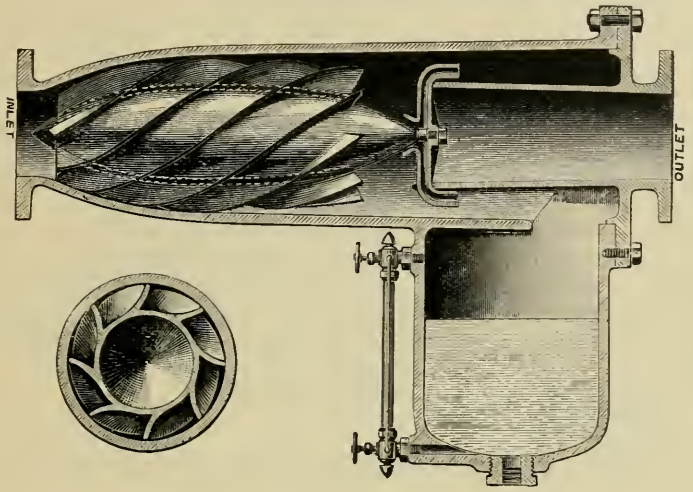
Neither of these methods of circulating the water in the boiler can be used after the boiler is under its full pressure.

CENTRIFUGAL SEPARATOR.

Art. 14.—(P. 123, S. & O.)

Figs. 110 and 111 of the text-book show a type of separator in common use. Another type, sometimes used in the U. S.

navy, consists of a cylindrical chamber with vanes so arranged as to give the entering steam a whirling motion and the water is thrown outward by centrifugal force. A chamber underneath collects the water and from thence it is trapped to the feed-tank. A separator of this kind is the " De Rycke," shown in Fig. 15.



(Fig. 15.)

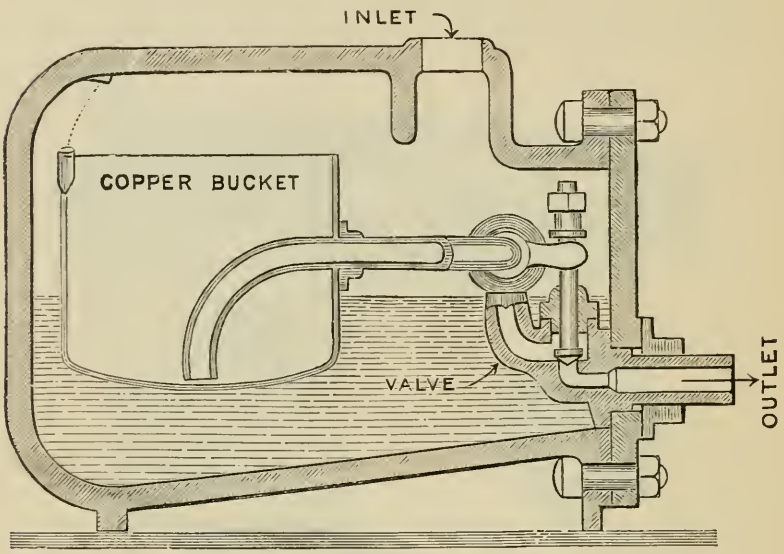
STEAM TRAPS.

Art. 15.—(P. 126, S. & O.)

There are various types of steam traps in use in the U. S. navy. The trap shown on p. 126 of the text-book represents one type, being similar to the Nason trap.

Another type consists of a chamber with an outlet valve operated from the end of a lever, with fulcrum near the valve. The other end of the lever carries a float or bucket. The normal position of the valve is closed, but when the chamber fills, the float, if used, rises and opens the valve. If a bucket be used, the bucket after rising to the top of the chamber is filled by the water flowing into it over the edge and, sinking to the bottom of the chamber, opens the discharge valve, allowing the discharge of the water from inside the bucket: the water in the trap being discharged down to the level of the top of the bucket, and the water in the bucket having been blown out, the bucket

rises, floating on the water remaining in the trap, and rising closes the discharge valve. A trap of this description is the "Dinkel" trap, shown in Fig. 16.



(Fig. 16.)

NOTE.

CALCULATION OF TABLE, P. 138 S. & O.

Art. 16.—Let U = the useful work done in a given time expressed in B. T. U.

Let Q = the heat expended in the same time to perform the work U.

Efficiency $= \frac{U}{Q} = \frac{T_1 - T_2}{T_1 + 461}$. The efficiency being a maximum, and T_1 and T_2 the limits of temperature between which the work is performed.

Let U = one I. H. P. $= \frac{33000}{772} = 42.75$ B. T. U. expended per minute.

Consequently, $Q = 42.75 \times \frac{T_1 + 461}{T_1 - T_2}$; T_1 and T_2 being the limits, the equation gives the minimum amount of heat which will produce one I. H. P. when working between these limits.

Let N = the number of pounds of steam per I. H. P. per hour.

Let H = heat necessary to form one pound of steam under the given conditions of temperature of feed and temperature of the steam formed. Then

$$N = \frac{60 \times Q}{H} = \text{pounds of steam per I. H. P. per hour.}$$

Example.—Case I; Condensing Engine.

$T_1 = 249$, $T_2 = 100$. Then $Q = 42.75 \times \frac{710}{149} = 203.49$.

$$N = \frac{60 \times 203.49}{1082 + .3 \times 249 - (100 - 32)} = 11.2$$

Example.—Case II; Non-Condensing Engine.

$T_1 = 249$, $T_2 = 212$. Then $Q = 819.945$.

$$N = \frac{60 \times 819.945}{1082 + .3 \times 249 - (212 - 32)} = 50.37.$$

NOTE.

CALCULATION OF MEAN EFFECTIVE PRESSURE WHEN A GAS EXPANDS ACCORDING TO ANY LAW.

Art. 17.—(Chap. XII., S. & O.)

Let p_1 = the initial pressure.
p_2 = " final "
p_3 = " back "
p_m = " mean absolute forward pressure.
p_e = " " effective pressure.
$p_e = p_m - p_3$.
v_1 = the initial volume.
v_2 = " final "

r = ratio of expansion $= \frac{v_2}{v_1}$,

p_m = the total area of the card, Fig. 54 (down to the axis V), divided by the length of the card, or $p_m = \frac{A}{v_2} = \frac{A}{rv_1}$.

Suppose the equation to the expansion curve of the diagram be $pv^n =$ a constant, the area of the portion bounded by the expansion curve and the vertical ordinates limiting it will be

(1) $$\int_{v_1}^{v_2} p\,dv\,;\ \text{but } pv^n = p_1v_1^n = p_2v_2^n = p_3v_3^n\,,\ \text{etc.,}$$

$$\text{from which we get } p = \frac{p_1v_1^n}{v^n}.$$

Substituting this value for p in the integral, the expression becomes

(2) $$\text{Expansion area} = \int_{v_1}^{v_2} p\,dv = \int_{v_1}^{v_2} p_1v_1^n\left(\frac{dv}{v^n}\right).$$

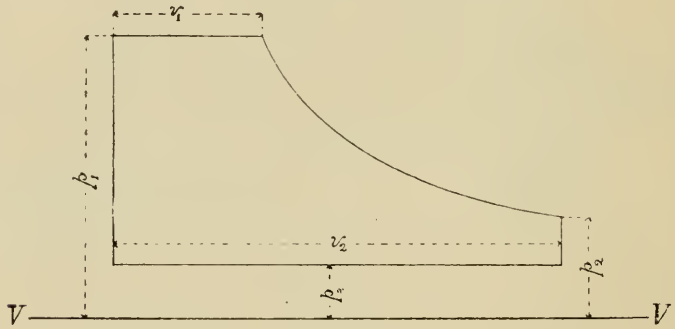


Fig. 17.

To this add the area of the rectangle p_1v_1, and the expression for the total area becomes:

(3) $$p_1v_1 + p_1v_1^n \int_{v_1}^{v_2} \frac{dv}{v^n}.$$

Integrating equation (3) between the limits, remembering that $v_2 = rv_1$;

(4) $$\text{Work area} = p_1v_1 + \frac{p_1v_1 - p_2v_2}{n-1} = p_1v_1 + p_1v_1^n\left(\frac{v^{1-n}}{1-n}\right)_{v_1}^{rv_1}.$$

$$\text{Then since } p_m = \frac{\text{Work area}}{rv_1},$$

(5) $$p_m = p_1 \times \frac{r^{1-n} - n}{r(1-n)} \text{ and } p_e = p_m - p_3\,.$$

Experiments have been made with steam under varying condi-

tions, and calculations from these experiments have shown the values of the coefficient n to be as given below:

(*a*) *Isothermal or Hyperbolic Expansion.* $pv = \text{constant}$.

The heat received from the jacket or other external source is exactly equivalent to the external work done.

(*b*) *Saturated Steam Expansion.* $pv^{\frac{17}{16}} = \text{constant}$.

The heat received from the jacket or other external source is just sufficient to keep the steam dry and saturated. The curve of expansion is called the *Saturated Steam Curve.*

(*c*) *Adiabatic Expansion.* $pv^{\frac{10}{9}} = \text{constant}$.

The steam expands in a non-conducting cylinder, doing work at the expense of the heat in the steam. No heat is received and none is lost *as heat.* An amount of heat is given up exactly equivalent to the work done. The curve of expansion is called the *Adiabatic Curve.*

Let $n = 1$; then the equation of the expansion curve becomes that of a rectangular hyperbola, and the expansion becomes hyperbolic and approaches that of a perfect gas.

Substituting this value for n, in equation (5), and evaluating, or better still, substituting in equation (3) and integrating; the expression for the mean absolute forward pressure becomes:

$$(6) \qquad p_m = p_1 \times \frac{1 + \text{hyp. log. } r}{r}.$$

$$(7) \qquad \text{When } n = \frac{17}{16},\ p_m = p_1 \times \left(\frac{17 - 16r^{-\frac{1}{16}}}{r}\right);$$

$$(8) \qquad \text{When } n = \frac{10}{9},\ p_m = p_1 \times \frac{10 - 9r^{-\frac{1}{9}}}{r};$$

NOTE.—The hyperbolic logarithm of any number can be found by multiplying the common logarithm of the number by 2.302585, or, as is usually done, by 2.30.

EXPLANATION OF TABLE, P. 142, S. & O.

Art. 18.—The specific volume, v, of steam may be calculated from the formula $pv^{\frac{17}{16}} = 475$. (See p. 146 of Sennett and Oram.)

Assuming the first column in the table, let

p_1 = initial pressure,

p_2 = final pressure,

$\frac{v'_2}{v'_1}$ = ratio of expansion.

then since $p_1 {v'_1}^{\frac{17}{16}} = p_2 {v'_2}^{\frac{17}{16}}$,

$$\text{ratio of expansion} = \frac{v'_2}{v'_1} = \left[\frac{p_1}{p_2}\right]^{\frac{16}{17}} = \left[\frac{p_1}{10}\right]^{\frac{16}{17}}.$$

Taking the case of dry saturated steam, the mean absolute pressure

$$p_m = p_1 \times \frac{17 - 16r^{-\frac{1}{16}}}{r};$$

and the mean effective pressure $p_e = p_m - p_3 = p_m - 3$.
The values given in the last column are obtained as follows:

Let sub 1 represent the first line of the table and sub 2 any other line; then when

L = length of the stroke of the engine in feet,

P = mean effective pressure per square inch on the piston,

A = area of the piston in square inches,

N = number of strokes of the engine per minute,

the engine being the same in the two cases, the pressures and revolutions varying only:

$$(\text{I. H. P.})_1 = \frac{P_1 LAN_1}{33000} \text{ and } (\text{I. H. P.})_2 = \frac{P_2 LAN_2}{33000}; \text{ from which}$$

$$(1) \qquad \frac{(\text{I. H. P.})_1}{(\text{I. H. P.})_2} = \frac{P_1 N_1}{P_2 N_2}.$$

But $PL = \frac{MV^2}{2g}$ and as V is proportional to N we may write $PL = KN^2$ where K is a constant; consequently

$$(2) \qquad \frac{P_1}{P_2} = \left[\frac{N_1}{N_2}\right]^2 \quad \text{or} \quad \frac{N_1}{N_2} = \left[\frac{P_1}{P_2}\right]^{\frac{1}{2}},$$

which substituted in (1) gives

$$(3) \qquad \frac{(\text{I. H. P.})_1}{(\text{I. H. P.})_2} = \left[\frac{P_1}{P_2}\right]^{\frac{3}{2}},$$

and by substituting known values in this equation, the results found in the last column may be calculated.

Problems on the Preceding Articles.

33. What are the least "pounds of coal per I. H. P. per hour," which would be used by a perfect engine having an initial pressure of steam of 180 pounds, where the temperature of the steam is 373° and of the feed-water 120°?

The coal used is considered thermally equal to pure carbon.

Ans. .5831 pounds.

34. The least "pounds of coal per I. H. P. per hour" expended in practice are 1.5 pounds.

As compared with the result of the preceding problem, what actual efficiency does this show for the modern engine?

Ans. .388.

35. How many pounds of water must be evaporated per hour under the conditions of question 33 to produce 1 I. H. P.?

Ans. 7.646 pounds.

36. An engine, the theoretical card of which is shown, makes 200 revolutions per minute.

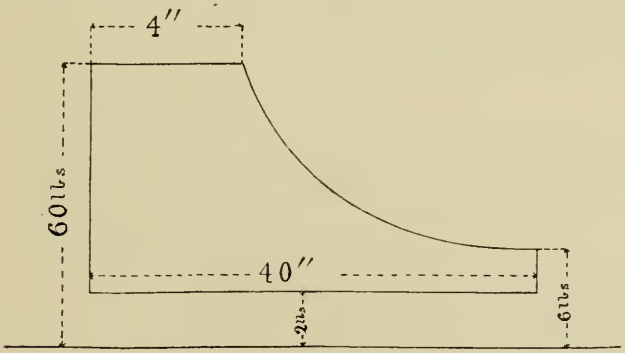


Fig. 18.

Area of piston = 300 square inches.

Stroke = 40 inches.

Cut-off is at 4 inches from beginning of stroke.

Temperature of feed = 110°.

Initial pressure of the steam = 60 pounds per square inch.

Initial temperature of the steam = 293°.

Required to find the I. H. P. developed by the engine, and the number of B. T. U. expended.

Ans. 215.7 I. H. P., 42500 B. T. U. expended per minute.

37. Find the efficiency of the engine of question 36.

Ans. 21.6 per cent.

38. With the steam used in question 36, find the maximum efficiency theoretically attainable if the steam be used in an engine. *Ans.* 22.2 per cent.

39. If this maximum efficiency be considered perfection, as is the case for steam between these temperatures, what is the efficiency of the engine? *Ans.* 97 per cent.

40. Suppose an engine to work between the limits of pressure of 100 pounds and 18 pounds per square inch, temperatures of the steam 327.5° and 222.4°; and then the same engine to work between the limits of 100 pounds and 2 pounds per square inch, temperatures of the steam 327.5° and 126.2°; compare the efficiency of the steam in the two methods of working.

Ans. As 105.1 is to 201.3.

41. Suppose the curve of expansion in each of the above cases of Problem 40, be $pv =$ a constant.

Compare the amount of work done by the same amount of steam in the two methods of working.

Ans. Work done in first case is to work done in second case as .553 is to 1.

42. In the table, given on p. 138 of the text, calculate the last line, taking the temperatures from the tables.

43. A cylinder full of steam of 4 pounds pressure per square inch and 153° temperature is discharged to a condenser at the end of each stroke of the engine.

The dimensions of the cylinder $= 3' \times 3'$.

It is desired to make the temperature of the condensed, or feed-water 110°, the temperature of the injection, or sea-water being 80°.

If a jet condenser be used, how many pounds of sea-water will be required per stroke of the engine as injection water?

Ans. 8.25 pounds.

44. Suppose that a surface condenser were used with the engine of question 43, and that the temperature of the discharge water were 100°, how many pounds of injection water would then be required per stroke? *Ans.* 12.38 pounds.

45. One pound of steam of 100 pounds pressure per square inch contains 20 per cent. moisture; what volume will it occupy?

Ans. 3.5256 cubic feet.

46. Calculate the second line of the table given on p. 142 of the text.

47. Calculate the last line of the table given on p. 142 of the text.

48. With an initial pressure of 100 pounds, a back pressure of 3 pounds, and a ratio of expansion of 12, calculate the mean effective pressure when dry steam expands in a jacketed cylinder and the jacket furnishes as much heat as is used up in work; in a non-conducting cylinder; in a jacketed cylinder, the jacket furnishing just enough heat to keep the steam dry throughout the stroke.

49. With the same conditions as to expansion, find the mean effective pressure, having given an initial pressure = 50 pounds, back pressure = 2 pounds, and a ratio of expansion = 4.

50. With the same conditions as to expansion, find the mean effective pressure, having given an initial pressure = 60 pounds, back pressure = 5 pounds, and a ratio of expansion = 10. Also find the final pressure.

In the following problems on change in I. H. P. for given changes in the performance of the engine, it is to be understood that the number of revolutions cannot change unless the mean effective pressure changes, the resistance remaining constant.

51. An engine making 50 revolutions per minute develops 200 I. H. P. Suppose that the revolutions are increased to 60 per minute; what will then be the I. H. P.? *Ans.* 345.6.

52. An engine is making 100 revolutions per minute, and the mean effective pressure, as shown by the card, is 15 pounds per square inch. If the mean effective pressure on the piston be increased to 20 pounds per square inch, what number of revolutions per minute may the engine be expected to make?

Ans. 115.47.

53. If, in question (52), the I. H. P. were, in the first instance, 250, what I. H. P. would be developed under the new conditions?

Ans. 384.9.

54. If the revolutions of an engine be doubled, what is the increase in the I. H. P.? *Ans.* Eight fold.

55. If the number of revolutions made by an engine be increased by 10 per cent., what is the percentage of increase in the I. H. P.? *Ans.* 33 per cent.

56. If the mean effective pressure on the piston of an engine be increased 10 per cent., what will be the percentage of increase in the I. H. P., and in the number of revolutions per minute?

Ans. 15 per cent. in I. H. P., and 5 per cent. in revolutions.

57. The I. H. P. varies as the number of revolutions of the engine raised to what power? *Ans.* To the third power.

NOTES ON THE ZEUNER VALVE DIAGRAM.

Art. 19.—(P. 184, S. & O.)

In the notes which follow it is assumed that the length of eccentric rod is infinite. This, as a matter of fact, is not true, but the ratio of length of eccentric-rod to throw of eccentric is so large that the error involved in the diagram is insignificant.

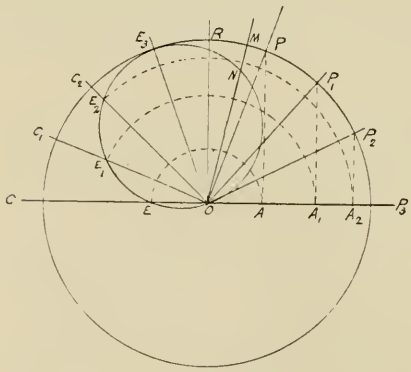


Fig. 19.

Suppose Fig. 19 to be drawn to a scale such that CP_3 represents the full travel of the valve. P represents the position of the eccentric when the crank is on the *dead centre*, at C. The angle POR then represents the angle of advance, and the distance OA represents the distance the valve has moved from its mid-position, at the beginning of the stroke.

If the crank moves to positions C_1, C_2, E_3, the eccentric moves through equal angles to corresponding positions P_1, P_2, P_3. As drawn the figure shows P_3 the position of the eccentric when the valve has reached its full travel to the right. It is evident that the crank at the same time reaches a position E_3, such that the angle ROE_3 = the angle of advance ROP. For the different positions C, C_1, C_2, E_3, of the crank, the travel of the valve from its mid-position is to OA, OA_1, OA_2, and OP_3, respectively.

Now sweep these positions around to E, E_1, E_2, and E_3, to the lines joining the centre with the corresponding positions of the crank. Join E_3 with any one of the other points, say with E_1. Then, in the triangles P_1OA_1 and E_3OE_1, we have the lines P_1O and OA_1 and the angle $P_1OA_1 =$ respectively to the lines E_3O and OE_1 and the angle E_3OE_1, by construction. Therefore, the triangles are equal and the angle E_3E_1O is equal to the angle P_1A_1O, which is a right angle. The point E_1 is therefore on a circle drawn on the line E_3O as a diameter.

This proves that if we take the crank as starting from the centre C, and turning to the right, and lay off an angle ROE_3 on the side next to the crank = to the angle of advance, and on OE_3 as a diameter, construct a circle:—a line drawn from the centre of the large circle to any position of the crank, such as M, will intercept a distance ON, = to the travel of the valve.

Lap.—When the valve is in its mid-position, the amount that it overlaps the edge of the port is called the *lap*. The amount that it overlaps on the steam side is called the *steam lap* and the amount that it overlaps on the exhaust side is called the *exhaust lap*. (The laps are sometimes spoken of as the inside and outside lap.) Before the steam port can open, the valve must travel a distance = to the lap. After it has opened, the amount of its opening will always = the travel — the lap. If, therefore, on the diagram (Fig. 20), a circle be drawn with radius $OM =$ the lap, the port opening for any position of the crank S will be the length of the intercept VW, between the valve circle and the lap circle. At the point K this gives the opening of the port $= O$. K therefore, is the point where the valve begins to open, and is called the *point of admission*. At P the opening is again $= O$, and this is the *point of cut-off*.

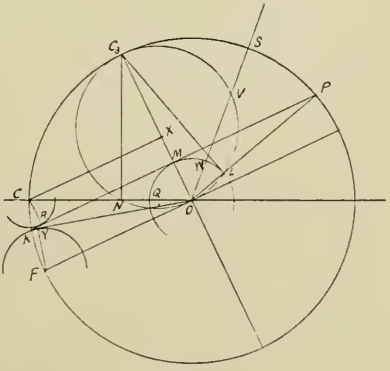


Fig. 20.

Lead.—The amount that the valve is opened to steam at the beginning of the stroke of the piston is called the *steam lead*. In Fig. 20 it is the length of the intercept

NQ on the line of dead centres. Similarly, the amount that the valve is opened to exhaust at the end of the stroke of piston, is called the *exhaust lead.*

Certain geometrical properties of the diagram will now be explained. By their aid, several of the problems are solved.

1. A perpendicular let fall from the point corresponding to the angle of advance (C_3, Fig. 20), cuts the line of dead centres at a distance from the centre = Lap + Lead.

This proposition is evident on examination of Fig. 20.

2. A line joining the points of admission and cut-off is tangent to the steam lap circle.

Proof.—In Fig. 20 the triangles C_3OL and POM have the sides PO and MO = respectively, to C_3O and LO, and the angle C_3OP is common. The triangles are therefore equal and angle PMO = angle C_3LO, which is a right angle. PM is therefore tangent to the lap circle.

3. If with centre at the dead point C, and radius = the Lead, a circle be drawn, it will be tangent to the line KP, joining the points of admission and cut-off.

Proof.—Through C draw CX parallel to KP, and therefore perpendicular to C_3O. The lines CO and C_3O are equal; angles OCX and OC_3N are equal; and angle COC_3 is common to both triangles. Therefore triangles COX and C_3ON are equal, $XO = NO$, and $XM = NQ$. But NQ = the Lead. Therefore $CR = XM$ = the Lead.

4. If OF be drawn perpendicular to OC_3, a perpendicular from F on the admission line, will be equal to the steam lap.

Proof.—It will be readily seen that triangles FOY and OKM are equal; therefore $FY = OM$.

This property is made use of in constructing the exhaust part of the diagram, whenever the lap circle is so small that it does not give a sharp intersection with the valve circle.

The foregoing has referred to the steam side of the valve particularly. The exhaust side is considered in the same way; but, with the piston making the return stroke, from P_3 to C. The diagram then comes in the lower half of the figure. The angle of advance and the travel of the valve are the same, but the lap is the inside or exhaust lap. The exhaust lead and the

points of release and compression correspond respectively to the steam lead and the points of admission and cut-off, and are obtained in the same way.

Fig. 21 shows a complete diagram, which gives the following information:

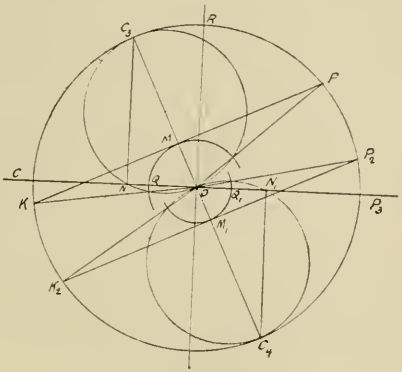


Fig. 21.

1. Admission at K, given by angle KOC.
2. Cut-off at P, given by angle POC.
3. Steam Lap $= OQ$.
4. Steam Lead $= NQ$.
5. Maximum opening of steam port $= C_3M$.
6. Angle of advance $= C_3OR$.
7. Travel of the valve $= CP_3$.
8. Release at P_2, given by angle P_2OP_3.
9. Compression at K_2, given by angle K_2OC.
10. Exhaust Lap $= OQ_1$.
11. Exhaust Lead $= N_1Q_1$.
12. Maximum opening of exhaust port $= C_4M_1$.

Points 1, 2, 9 and 10 must be given, and are measured on the valve diagram, by the *angular* distances of the crank from the beginning or end of the stroke, corresponding to these points. Frequently these points are given in data for problems, as taking place at a certain part of the stroke. In order to find the angular position corresponding to such data, the circle representing the travel of the valve must be made to represent, temporarily, the crank circle on a new scale; or, a second circle of reference, representing the crank circle, may be drawn. A good plan is to draw it concentric with the valve diagram.

Suppose the cut-off to be given as at $\frac{5}{8}$ of the stroke. Draw the *crank* circle CPP_3 (Fig. 22), CP_3 representing the stroke of the engine. Lay off $CA = \frac{5}{8}$ of CP_3, and with a radius $=$ length of connecting rod, on the scale of the diagram, sweep A up to P. Angle COP is the angular distance from the beginning of the stroke at which cut-off takes place. This angle can then be transferred to the valve diagram.

Points 1—7 belong to the steam side of the diagram and points 6—12 to the exhaust side, points 6 and 7 being common to both sides. To construct the complete diagram it is necessary to have four of these points. Three are sufficient to construct the steam or exhaust side alone; but one or two of the points must belong to a different side from the others, to construct the complete diagram. One of the points must be one of the *linear* measurements on the diagram, *i. e.* points 3, 4, 5, 7, 10, 11, or 12. This is seen from the fact that with only *angles* given, the *linear* dimensions of the valve might be made anything we please, except that they must bear a certain ratio to one another.

The *width of port* in the face of cylinder is often given as a part of the data. This may be taken as the maximum opening of the exhaust port, since the opening to exhaust will be greater than the opening to steam, and the port is only made sufficiently wide to allow full opening.

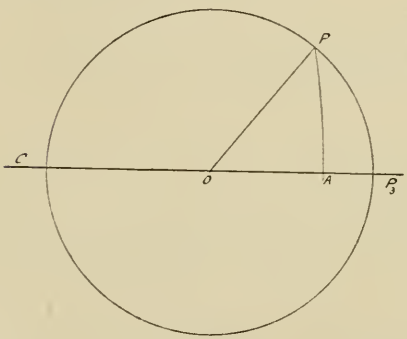


Fig. 22.

Problem I.—Given *travel of valve* and points of *admission, cut-off* and *release.*

Referring to Fig. 21; let CP_3 = the given travel. On CP_3 as a diameter, construct the circle CPC_4. K, P and P_2 are the given points, found with the data given. Through K and P draw KP, through O draw C_3C_4 perpendicular to KP, and through P_2 draw P_2K_1 parallel to KP. M and M_1 are thus given and, by drawing the valve circles on OC_3 and OC_4 and the lap circles through M and M_1, the leads are given.

Problem II.—Given *travel of valve, steam lap, steam lead,* and any point in the exhaust diagram.

Construct the circle CPC_4 as before. Lay off ON = lap + lead, and erect the perpendicular NC_3. C_3OR is the angle of advance. The remainder of the construction will be plain.

Problem III.—Given *travel of valve, cut-off, steam lead,* and *exhaust lap.*

Construct the circle CPC_4 as before and mark the point P with the data given. With centre C and radius = the lead, draw a circle. Through P draw a line passing tangent to this circle below C. This cuts the large circle in K, the point of admission. Draw a diameter to the large circle perpendicular to KP. This gives the angle of advance and the remainder of the construction will be plain.

PROBLEM IV.—Given *steam lap, steam lead,* and the *point of cut-off.*

In Fig. 21, let COP = the angle corresponding to the point of cut-off. Draw the lap circle QL, and lay off QN = the given lead. Construct a circle passing through the three points N, O, and L. This will be the valve circle and its diameter = the half travel of the valve.

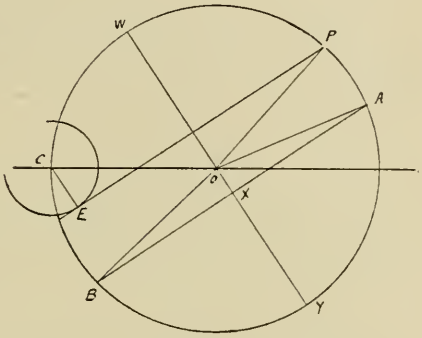


Fig. 23.

PROBLEM V.—Given *cut-off, release, compression,* and *width of port.*

The *width of port* is taken as equivalent to the *maximum opening of exhaust port.*

Draw a circle of indefinite radius (Fig. 23) and mark on it the points of cut-off, release, and compression. Join the points of release and compression by the line AB, and through O draw a diameter perpendicular to AB. Then:

$$\frac{\text{Travel of valve}}{\text{given width of port}} = \frac{WY}{XY}.$$

From this the travel of the valve is obtained and the diagram may be constructed. If the lead is given instead of the width of port: through P draw a line parallel to AB and from C let fall a perpendicular CE upon it. Then

$$\frac{\text{Travel of valve}}{\text{given lead}} = \frac{WY}{CE}.$$

Problems.

Note.—Bring paper, dividers and scale to this recitation.

Note.—In the following problems will be found many badly arranged valves; some of them would probably not permit the engine to work. In such cases the student will be required to show what alterations should be made to secure efficiency.

58. The travel of a valve is 6″. The cut-off occurs when the crank has completed 105° of its path. Admission of steam begins when the crank is within 7.5° of the beginning of its stroke. Exhaust closes when crank is 60° from the end of its stroke.

Construct the Zeuner valve diagram and find:

Steam lap; steam lead; exhaust lap; exhaust lead; angle of advance.

59. Travel of the valve = 5″. Steam lap = 1″. Exhaust lap = ½″. Steam lead = ½″.

Find and measure the angle of advance.

If the stroke of the engine = 4′, and the connecting rod be considered as infinite, how far is the piston from the end of its stroke when cut-off occurs?

60. What should be the steam lap of the valve in the preceding question, so that the steam would be cut off at half stroke?

61. What angle of advance should be given the valve of the engine of question 59, so that it would cut off at half stroke?

How would this change affect the other functions of the valve?

62. Stroke of engine = 3′. Length of the connecting rod = 5′. The valve has an exhaust lap of ¼″, and a steam lap of 1″. The maximum port opening for exhaust is 2.75″. Compression begins when the piston is 12″ from the end of its stroke.

Find the travel of the valve, and the angle of advance.

63. The valve, a sketch of which is shown, is to have a travel just sufficient to open the port wide for exhaust when the exhaust is a maximum.

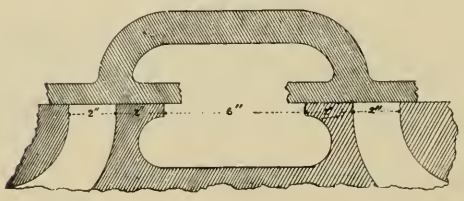


Fig. 24.

With an infinite connecting rod, it is to cut off at .75 of the stroke of the engine.

The exhaust is to begin to open when the piston is at $\frac{1}{8}$ of its stroke from the end, and the admission to occur $\frac{1}{16}$ of the stroke from the end of the stroke of the piston.

Find the steam and exhaust laps, the travel of the valve, the angle of advance of the eccentric, and the position of the piston at exhaust closure.

64. In a given engine the cut-off is to occur when the crank is within 45° of the end of its stroke, the release within 15° of the end of the stroke, and the admission to begin 7.5° from the beginning of the stroke.

Maximum exhaust port opening 2.5 inches.

Find the travel of the valve, steam and exhaust laps, crank angle when compression begins, and the steam and exhaust leads.

65. Stroke of an engine = 3′. Length of its connecting rod = 5′.

When cut-off occurs, the piston is 2′ from the beginning of the stroke. When release occurs, the piston is 5″ from the end of the stroke, and when compression begins, at 10″ from the end of the stroke. The maximum opening of the port for steam is 1″, and for exhaust is 2″.

Construct the diagram and measure the angular advance.

Make a section of the valve and its seat to a scale of 3″ = 1′, and show the dimensions of all the parts.

66. Steam lap = 2″; exhaust lap = 1″; angle of advance = 30°; cut-off at .75 of the stroke. Having an infinite connecting rod, construct the diagram.

This diagram being that of an engine with link in full gear, show how it would be affected by *open rods;* by *crossed rods;* and by raising the link in each case one-half.

If, instead of a *link motion*, a *radial gear* be used and the *cut-off* be shortened by raising the *reversing lever*, show how the diagram would be affected.

67. Travel of the valve = 6″; cut-off at half stroke; angle of advance of the eccentric = 30°; exhaust lap = ½″. Construct the diagram.

(*a*) Construct the theoretical indicator card, with an initial pressure of 100 pounds to the square inch, the scale of the indicator being 25 pounds = 1″, and the curve of expansion having the form pv = a constant.

(*b*) If the angular advance be diminished, show how the diagram and the indicator card will be affected.

(*c*) What alteration in the data might be made so that an earlier exhaust closure would follow?

68. Steam lead = ½″; steam lap = 1″; exhaust lead = ¾″; travel of the valve = 3″.

Construct the diagram and make a sketch of the valve and its seat to a scale of 4″ = 1′. Mark all the dimensions on the sketch.

69. If the stroke of the piston of the above engine be 3′, sketch the theoretical indicator card. The initial pressure is 80 pounds per square inch, and the scale of the indicator is 30 pounds = 1″. The curve of expansion is of the form given by the equation pv = a constant.

Art. 20—(P. 261, S. & O.)

In ships having double bottoms, it is necessary to fit a special nozzle for all valves which are intended to admit sea water for various uses on board.

Fig. 25 shows one method of doing this, the nozzle being shown part in elevation and part in section.

In the outer bottom *b* a hole is cut, around which, to compensate for the loss of strength due to cutting away the metal, is riveted a cast steel ring *c* in which are fitted a number of stud bolts. A *zinc ring k* is fitted snugly in the hole thus made, and is secured to the ring *c* with countersunk screws, as shown.

A hole having been cut in the inner bottom *a*, large enough to permit the passage of the bottom flange of the nozzle *d*, this nozzle is then passed through and secured to the stud bolts in *c*. The nozzle *d* has an inner flange, in which are screwed several stud bolts *h*, whose middle unthreaded portions are square. Over these studs is fitted the grating *g*, having square holes to correspond to the square studs, and nuts are screwed on the ends of the studs and secured with split-pins run through holes in the studs.

A plate *f*, having a stuffing-box cast with it, is then passed over the end of the nozzle, and is bolted to the inner bottom *a*. Stud bolts are screwed in *f* around the *stuffing-box*, and serve to hold in place the *gland*, which is passed over the end of the nozzle

and screwed down after the stuffing-box has been filled with several turns of *square flax packing*. Last of all the flange *e* is screwed on the end of the nozzle which has been threaded for this purpose.

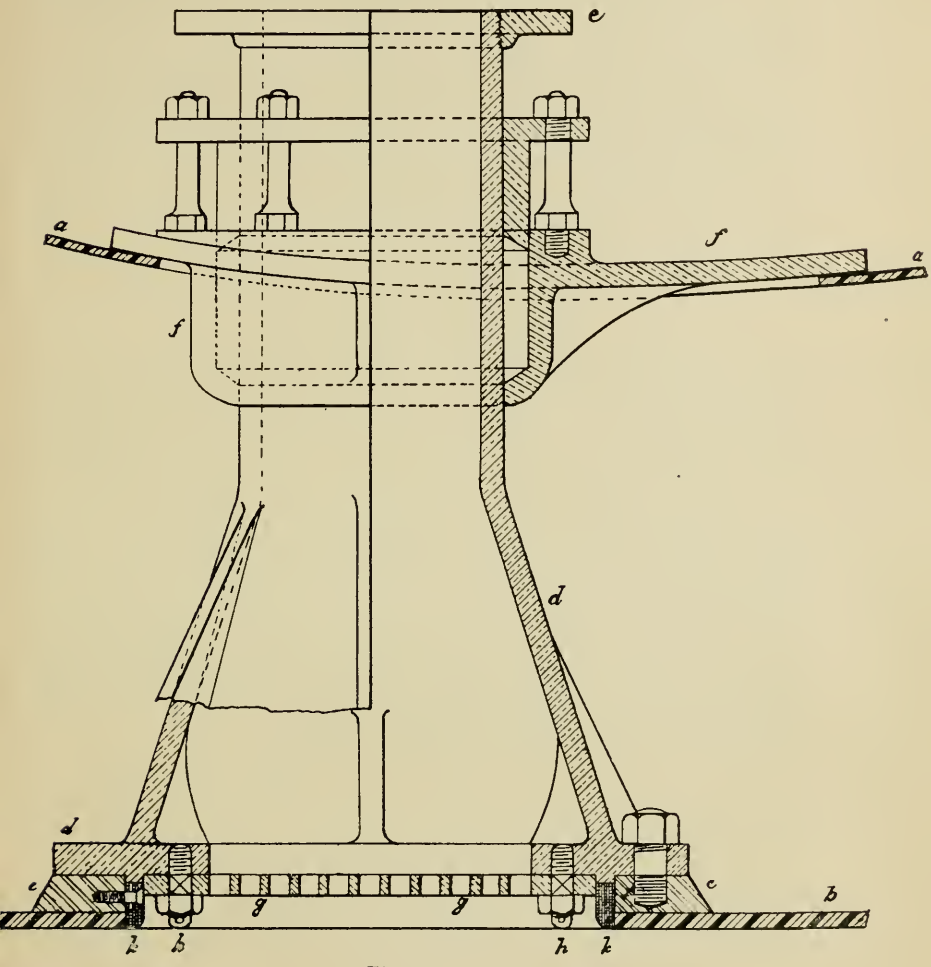


Fig. 25.

The zinc ring *k* protects the bottom of the ship from pitting by being eaten away gradually during the electrolytic action which is set up by running salt water through the steel skin of the ship and the composition nozzle.

The grating g prevents the entrance of large pieces of foreign matter, and can be readily removed, if necessary, when in dock. The area of the holes in this is about 1.75 times the area of the valve attached to the nozzle, and this excess area and the large conical mouth of the nozzle permit the inner pipe to receive a full supply of water.

Should the ship ground and the outer bottom be pierced, the water cannot pass the inner bottom, and if the outer bottom be sprung, the nozzle, being free to move, will not be broken away, nor will the inner bottom be affected.

The upper flange e must be screwed on, as otherwise the stuffing-box and gland could not be passed over the nozzle.

Problems.

(To follow p. 267, S. & O.)

70. The temperature of the steam = 300°. Saturation to be maintained = $\frac{3}{32}$. Density of the feed water = $\frac{1}{32}$, and temperature of the feed = 60°. What percentage of the heat is lost by blowing off? *Ans.* 9.5 per cent.

71. The temperature of the steam = 300°, temperature of the feed = 75°, and the density of the feed = $\frac{1}{32}$. What percentage in gain of heat will there be if the density in the boiler be carried at $\frac{5}{32}$ instead of $\frac{1 \cdot 7.5}{32}$? *Ans.* 16.2 per cent.

72. The temperature of the steam = 250°. Temperature of the feed = 60°. Density of feed = $\frac{1}{32}$. Density to be maintained = $\frac{6}{32}$. Find the percentage of loss of heat due to blowing off in order to keep the saturation constant. *Ans.* 3.25 per cent.

73. The temperature of the steam is 325°, and of the feed 32°. The density to be maintained is $\frac{4}{32}$, and the density of the feed is $\frac{0 \cdot 5}{32}$.

Find the percentage of loss due to blowing off the boiler to maintain a constant saturation. *Ans.* 3.42 per cent.

74. The density to be maintained is $\frac{1 \cdot 5}{32}$. The temperature of the feed is 100° and its density is $\frac{1}{32}$. The temperature of the steam is 275°.

Find the loss due to blowing off the boiler to maintain a constant saturation. *Ans.* 24 per cent.

75. Density to be maintained is $\frac{6}{32}$. The other data are the same as in the preceding problem.

Find the amount of feed water necessary that there may constantly be delivered to the engine an amount of steam sufficient to produce a mean piston speed of 900 feet per minute.

The cylinder is 3′ in diameter, has a stroke of 3′, and cuts off at .75 of its stroke. 536.5

NOTE.—The commercial horse power of a boiler is measured by the evaporative efficiency of the boiler.

If a boiler evaporate 30 pounds of water per hour, from feed water having a temperature of 100° to steam of 70 pounds pressure per square inch, it is said to develop one commercial horse power.

76. How many pounds of water must be evaporated, from and at 212°, to be equivalent to one commercial horse power?

Ans. 34.488 pounds.

77. How many heat units are there in one commercial horse power? *Ans.* 33,189.

78. What would be the commercial horse power of the boiler required to supply steam to the engine of Problem 75?

Ans. 1060.7 commercial horse power.

79. A steam cutter engine has a cylinder 6″ in diameter, and the stroke of the engine is 6″. The cut-off is at .75 of the stroke; the initial pressure of the steam is 80 pounds per square inch; the temperature of the feed is 76°, and the engine makes 300 revolutions per minute. What must be the commercial horse power of the boiler necessary to supply this engine with steam?

Ans. 19.425 commercial horse power.

NOTES ON THE STEAM TURBINE.

Art. 21.—(Chap. XXII, S. & O.)

The following notes are intended merely to give a general idea of the steam turbine, with some data on its economical performance.

At present the two leading turbines are the *Parsons* and the *De Laval.*

The first large installation of steam turbines was in 1891, when the electric light station at Cambridge, England, was fitted with alternating current machines, driven by Parsons' Improved Com-

pound Condensing Steam Turbines, directly connected. The installation was thoroughly tested by Prof. Ewing, F. R. S., Professor of Engineering at the University of Cambridge. These tests showed a steam consumption of 74.5 pounds per kilowatt-hour, with very light load; 32.2 pounds, with half load; and 28.4 pounds, with full load; using steam very slightly superheated. The turbine cannot be indicated as the reciprocating engine can, and the measure of work must be the actual work performed. By constructing curves of work, somewhat similar to the curves of indicated thrust, constructed by Dr. Froude (Sennett & Oram, p. 302), Prof. Ewing estimated the idle work to be about 25 per cent. and the efficiency about 75 per cent. On this basis, the steam consumed, per I. H. P., was about 15.5 pounds at full load, and about 17 pounds at half load. These results showed the marked superiority of the turbine at light loads, and its efficiency compares well with that of the best reciprocating engine at full loads.

Further tests were made to show the effect, on efficiency, of using steam highly superheated. It was shown that by superheating the steam sufficiently to cause it to be dry at the end of the expansion, a marked saving was effected; and further superheating did but little good.

This turbine is described by Prof. Ewing as follows:

The turbine case contains a series of seven revolving discs, from the surface of which the turbine blades project. They are arranged on each disc in a series of concentric rings. The fixed guide blades stand in spaces between these rings, being carried by annular discs which are fixed to the case. Thus each revolving disc, with its neighboring fixed disc, forms a series of outward flow turbines, the steam entering the series inside the smallest ring of blades and escaping at the circumference into a channel, which conducts it between the backs of the revolving disc and of the next fixed disc to the inside of the next series of rings. The heights and apertures of the turbine blades on each disc are adapted to the increasing volume of the steam, as it expands from an absolute pressure of 115 pounds per square inch to an absolute pressure of one pound per square inch. The first six discs, which are each 15 inches in diameter, are designed to expand the steam to about atmospheric pressure, the remainder of the expansion being performed in passing the sev-

enth disc, which is 26¾ inches in diameter, and has (unlike the other six) a double series of rings of blades, one series on each side, through which the steam flows in parallel. The height to which the turbine blades project above the discs in which they are secured, varies from $\frac{3}{16}$ inch to 1 inch. The whole number of rings of moving blades, in the machine tested, was 35. The blades are made of strong sheet brass and show no sign of wear, after continued use. Steam enters the turbine case at one end through a double-beat valve, and, after passing the successive turbine discs, is discharged to a condenser.

The longitudinal pressure on the turbine shaft, due to the one-sided character of the turbine discs, is taken up by a special form of thrust bearing. This thrust bearing, like the main bearings, runs in a bath of oil.

The governing of the machine was accomplished as follows: Steam was admitted to the turbine in a series of gusts, by the periodic opening and closing of the double-beat lift valve. This valve was operated by means of a steam relay, in mechanical connection with the turbine shaft, so that the valve was opened regularly, once in every 28 revolutions of the shaft. The duration of each gust was controlled by an electric solenoid, which was connected as a shunt to the field magnets, but was compounded so as to keep the voltage constant. The effect was that at full load the gusts became blended into an almost continuous blast, the lift valve closing only momentarily, or not at all, in each of the periodic movements. Under any lighter load, each interval of admission alternated with an interval, during which the steam was entirely shut off. The action of this governor was most satisfactory. The speed was maintained constant, and there was no variation of voltage, sensible on a voltmeter.

In De Laval's turbine, the vanes are concave and are cut on the periphery of a thick disc, a band being afterwards shrunk on. The nozzle is directed against the plane of the disc at a small angle and tangentially against the circumference of the mean periphery of the blades.

The action is described as follows:

The steam expands to the back pressure, in the nozzle, before reaching the blades. This expansion is caused by making the sides of the nozzle diverging. The specific volume is thereby increased. As it passes on, the nozzle is again contracted, its velocity is increased, and thereby its momentum is increased.

Steam, at a pressure of 75 pounds, discharging at a pressure of 1.5 pounds, moves at a velocity of 4600 feet per second. The energy, $\frac{mv^2}{2}$, will be large, although the density will be small.

The Laval turbine differs from all others in that the full expansion of the steam takes place before reaching the blades, as already described, the full amount of statical energy being converted into dynamical. Also, other makers have tried to reduce the number of revolutions in their machines, while in the Laval this has not been the case. A 5 H. P. Laval turbine, 4″ in diameter, makes 30,000 revolutions per minute; one of 50 H. P., 12″ diam., 16,000 revs.; and one of 100 H. P., 20″ diam., 13,000 revs. These high speeds are obtained without being accompanied by vibration owing to the adoption of a flexible spindle, to which the turbine is attached. The speed is reduced, by gearing, down to a suitable degree for direct driving of dynamos or other machinery.

A number of nozzles discharge steam against the blades in the same wheel and the machine is governed by an automatic arrangement which cuts off a part of these.

There would seem to be no limit to the steam pressure that can be used with this machine. Mons. de Laval equips his turbines with a special form of steam generator that supplies steam of from 50 to 220 atmospheres. *The Engineer* of Aug. 12, 1898, describes a plant of this character which was installed at the Stockholm Exhibition. It says: "The steam consumption of a turbine of 100 horse power was 17.38 pounds per effective electrical horse power. For a steam turbine of 300 horse power under the same conditions, the steam consumption, it is stated, would be 12.54 pounds, and in fact it is hoped to reach a consumption of 7.7 pounds per effective electrical horse power for a turbine of this size."

In all turbines the steam does its work by impact on the turbine blades and economy is effected by the great range of expansion, which is carried to about one pound above the exhaust pressure.

The steam turbine possesses peculiar advantages for driving dynamos. (1) It may be directly connected to high speed dynamos, running from 2000 to 2500 revolutions per minute. (2) It is much cheaper, lighter, and takes up much less space. (3) There is a complete absence of vibration, which simplifies the

fitting of a proper foundation and renders it unnecessary to fit strong holding down bolts. (4) Internal lubrication is unnecessary and superheated steam may be used without injury, thus promoting the more efficient working of the engine. (5) It is more economical under the variable loads to which dynamos are subject.

An extended article on the theory of the steam turbine, by M. K. Sosnowski, will be found in the American Engineer and R. R. Journal, September, 1895, p. 405, *et seq.* (In N. A. library.) Other references, from which these notes are compiled are as follows: The Engineer, Oct. 11, 1895, p. 358; Electrical Engineer, Nov. 11, 1897, p. 449; Engineering, Nov. 26, 1897, p. 644; Journal American Society of Naval Engineers, Vol. V., p. 889.

The *Turbinia.*

The following information and data is collected from papers read before the Institute of Naval Architects and the Institution of Civil Engineers, by Hon. Charles A. Parsons. (Journal Am. Soc. Naval Engrs., May and August, 1897.)

In April, 1897, it was estimated that the total I. H. P. of steam turbines, at work in England, exceeded 30,000. A steam consumption of 14 pounds per I. H. P. has been ascertained, for engines of 200 I. H. P., and a still lower consumption is shown by larger engines.

In January, 1894, a syndicate was formed to test thoroughly the application of the steam turbine to marine propulsion, and a boat was designed for the purpose. The Turbinia, as the boat was named, is 100 feet in length, 9 feet beam, 3 feet draft amidships, and 44½ tons displacement. The original turbine engine in her was designed to develop upwards of 1500 actual horse power at a speed of 2500 revolutions per minute.

The compound steam turbine, fitted in her, consists of a series of steam turbines, set one after another on the same axis, so that each turbine takes steam from the preceding one and passes it on to the succeeding one. Each turbine of the set consists of a ring of fixed blades, called guides, fixed to the casing, and also a ring of moving blades, attached to the shaft. The steam from the steam pipe, entering all around the shaft, passes through the first set of guides, then through the first set of moving blades, then through the second set of guides, then through a second set of moving blades, and so on through the complete

turbine motor. The blades are carefully shaped as in water turbines, and the action of the steam in each turbine of the set is similar to that of water in the water turbine.

Steam is, however, an expansive fluid, and though its action in each individual turbine is approximately as if the fluid was inelastic, yet a small increment of volume takes place at each passage through the blades, and the expansion going on at something like geometric ratio at each of the numerous successive turbines, soon assumes large proportions. Ratios of expansion of fifty up to one hundred or even two hundred fold are common in one single compound turbine of the condensing type—a common notable feature in turbine practice being, that high expansion ratios and very large volumes can be economically dealt with, without necessarily increasing the size and weight of the engine to any large extent. What is perhaps more important, and gives the turbine a special advantage over ordinary engines, is that practically no increase in frictional resistances is incurred by arranging for the extra expansion, and exceptional economy in steam is thereby realized.

The boiler is of the water tube type for 225 pounds per square inch working pressure, with large steam space, and large return water legs, and with a total heating surface of 1100 square feet and a grate surface of 42 square feet; two firing doors are provided, one at each end. The stokeholds are closed, and the draft furnished by a fan coupled directly to the engine shaft. The condenser is of large size, having 4200 square feet of cooling surface; the circulating water is fed by scoops, which are hinged and reversible, so that a complete reversal of the flow of water can be obtained should the flow of water be choked. The auxiliary machinery consists of main air pump and spare air pump, main and spare feed pumps, main and spare oil pumps, also the usual bilge ejectors. No distilling apparatus is fitted. The fresh water tank and hot well contain about 250 gallons.

The approximate weights are:

Main engines	3 tons 13 cwt.
Total weight of machinery and boilers, screws and shafting, tanks, etc	22 tons.
Weight of hull, complete	15 tons.
Coal and water	7 tons 10 cwt.
Total displacement	44½ tons.

Trials were made with screws of various patterns, but the results were unsatisfactory, and it was apparent that a great loss of power was taking place in the screw. In the meantime trials of H. M. S. Daring had taken place, which had called attention to the phenomena of *cavitation*.

To investigate the question of cavitation, a spring torsional dynamometer was constructed, and fitted between the engine and screw shaft, measuring the actual torque transmitted. The measurements conclusively proved that the cause of failure lay entirely in the screws, and, with the object of further investigating the character of this waste of power, a series of experiments was made with model two-bladed screws of 2 inches diameter, revolved in a bath of water heated to within a few degrees of the boiling point, and, in order that the model screw should produce analogous results to the real screw, it was arranged that the temperature of the water and the head of water above the propeller, as well as the speed of revolution, should be such as to closely resemble the actual conditions and forces at work in the real screw, the object in heating the water being to obtain an increased vapor pressure from the water so as to permit a representation of the conditions with a more moderate and convenient speed of revolution than would otherwise have been necessary.

The screw was illuminated by light from an arc lamp reflected from a revolving mirror attached to the screw shaft, which fell on it at one point only of the revolution, and by this means the shape, form, and growth of the cavities could be clearly seen and traced as if stationary. It appeared that a cavity or blister first formed a little behind the leading edge, and near the tip of the blade; then, as the speed of revolution was increased, it enlarged in all directions until, at a speed corresponding to that in the Turbinia's propeller, it had grown so as to cover a sector of the screw disc of 90°. When the speed was still further increased, the screw, as a whole, revolved in a cylindrical cavity, from one end of which the blades scraped off layers of solid water, delivering them on to the other. In this extreme case nearly the whole energy of the screw was expended in maintaining this vacuous state. It also appeared that when the cavity had grown to be a little larger than the width of the blade, the leading edge acted like a wedge, the forward side of the edge giving negative thrust.

From these experiments it would appear that in all screws, of whatever slip ratio, there will be a limiting speed of blade, depending upon the slip ratio and the curvature of the back—in other words, on the slip ratio and thickness of blade; beyond this speed a great loss of power will occur; and that should the speed of ship be still further increased, the adoption of somewhat larger pitch ratios than those at present usual will be found desirable.

Following these experiments the single compound turbine engine was removed from the boat and replaced by three separate compound turbines, directly coupled to three screw shafts, the turbines working in series on the steam, being the high pressure, intermediate, and low pressure, and designed for a complete expansion of the steam of one hundred fold, each turbine exerting approximately one-third of the whole power developed, the three new screw shafts being of reduced scantling. Each shaft carries three two-bladed screws, 18 inches in diameter, making nine in all, thus greatly increasing the screw surface. These shafts are slightly inclined, by which the after screws are caused to work in water that is partially undisturbed.

By these changes the trouble from cavitation was obviated, and the power delivered to each screw shaft was reduced to one-third, while the division of the engine into three was favorable to the compactness and efficient working of the turbines. The total weight of engines and the speed of revolution remained the same as before. The effect on the screws was to reduce their scantlings and to bring their conditions of working closer to those of ordinary practice. The thrust of the propellers is balanced by steam pressure in the motors, no ordinary thrust bearings being fitted.

At all speeds the boat travels with an almost complete absence of vibration, and the steady flow of steam to the motors may have some influence on priming, no sign of it having occurred. The boat has been run at nearly full speed in rough water, and no evidence of gyroscopic action has been observable, though such a result would be anticipated from the known small amount of these forces under actual conditions in other boats.

Another report of the trials says that, when going full speed, the writer could not tell, by placing his hand on it, whether the motor was going or not; and the only vibration was due to the air pump, which was driven by a reciprocating engine.

The oiling of the main engines is carried on automatically, under a pressure of 10 pounds per square inch, by a small pump worked off the air pump engine; a small independent duplex oil pump is also fitted as a standby. The main engines require practically no attendance, beyond the regulation of a small amount of live steam, to pack the glands and maintain a good vacuum.

The advantages claimed for the compound steam turbine, over ordinary engines, for marine use, are as follows:

1. Increased speed.
2. Increased economy of steam, due to the high rate of expansion.
3. Increased carrying power of vessel.
4. Increased facilities for navigating shallow waters.
5. Increased stability of vessel.
6. Increased safety of the machinery for war purposes.
7. Reduced weight of the machinery.
8. Reduced space occupied by machinery.
9. Reduced initial cost.
10. Reduced cost of attendance on machinery.
11. Diminished cost of repairs of machinery.
12. Absence of vibration.
13. Reduced size and weight of screw propellers and shafting.

Mr. Parsons mentions no disadvantages in this connection, but the principal one lies in the difficulty of reversing the motion of the vessel. In the Turbinia, this is accomplished by having a small turbine on the centre shaft, with vanes in the reverse direction to those of the main engines, which can drive the boat sternward at a very low speed.

It is further claimed by Mr. Parsons, "that the substitution of steam turbines in place of reciprocating engines, in vessels of the largest size, and of fast or moderately fast speeds, presents advantages greater than those which have been realized in the little vessel Turbinia, and it may be roughly stated that for such vessels the speed of rotation would be slow, from 250 to 500 revolutions per minute, and the relative simplicity of these engines would become still more marked than is the case in the Turbinia's engines, indicating 2400 I. H. P., and giving her a velocity of 35 knots, or over 40 miles per hour, with an expenditure of steam of 14 pounds per I. H. P. per hour."

TRIALS.—The most successful trials, to date (Sep. 1898), of which accounts have been published, were made in April 1897. The mean of two consecutive runs gave a speed of 31.01 knots, the mean revolutions of the engines being 2100 per minute, the fastest run being at the rate of 32.61 knots.

The utmost horse power required to drive the boat at the speed of 31.01 knots is 945, as calculated from experiments on a model made at Heaton Works, on the method of the late Mr. William Froude.

Assuming the rate of thrust horse power to indicated horse power to be 60 per cent. (which appears to be the ascertained ratio for torpedo boats and ships of fine lines), the equivalent I. H. P., for 31.01 knots, is 1576.

The consumption of steam at 31.01 knots was approximately 25,000 pounds per hour; or, 15.86 pounds per I. H. P. per hour. It should be observed that the assumption of the thrust horse power being 60 per cent. of the I. H. P. presupposes that the propellers are of the best form obtainable; and, should those fitted be superseded by others of higher efficiency, as is possible, then the figures of consumption per I. H. P. will be correspondingly improved and the speed of the boat increased.

At present the inability to reverse quickly is the obstacle to fitting the turbine in torpedo boats. It is reported, however, that two torpedo-boat destroyers are now (September 1898) being built at Wallsend on the Tyne, which are to be fitted with turbines. A speed of forty knots is expected. Thirty-five knots when going ahead and seventeen knots when backing are guaranteed. One of these boats is for the British government and the other for a foreign government.

THE THEORY OF CAVITATION.

Art. 22.

Extracts from a paper read at the International Congress of Naval Architects and Marine Engineers, by Sydney W. Barnaby, Journal Am. Soc. Naval Engrs., November, 1897, p. 678:

If a cavity be formed in any manner in the interior of a mass of water it will tend to become filled with water vapor and with any air which might be in solution, since ebulition takes place at ordinary temperatures in a vacuum.

The trials of the Daring disclosed the following facts: With a pair of three-bladed screws 6.16 feet in diameter, 9 feet mean pitch, and 8.92 square feet developed surface, the Daring attained a speed of 24 knots with 3700 I. H. P., the screws making 30 per cent. slip. With a pair of screws of the same diameter, and practically the same mean pitch, but with a surface of 12.9 square feet—an addition of 45 per cent. to the surface—the same speed was obtained with 650 less horse power, and with 17¾ per cent. slip instead of 30 per cent. The number of revolutions required for 24 knots with the screws of small area sufficed to drive the vessel at 28.4 knots when the blade area was increased. The vibration was unprecedented and dangerous with the narrow blades; it was of quite a normal and unimportant character when the blades were widened.

In order to arrive at a clear understanding of what is believed to take place, it is necessary to distinguish between the two cases —first, that of a propeller drawing air from the surface; and second, that of the formation of cavities when the propeller is submerged. The effect upon the thrust of a fast-running screw when the blades break the surface of the water or when air penetrates from the surface is well known. Under such conditions the velocity under which water can flow, due to gravity at a depth h below the surface, is equal $\sqrt{2gh}$, and amounts, for example, to only 8½ knots at a depth of one meter.

If the velocity with which a portion of the blade situated at a depth h moves, is less than $\sqrt{2gh}$, the water will keep in contact with it, even if the blade break the surface, and there will be no loss of efficiency.

When the screw is sufficiently submerged to exclude air from the surface, the rate at which the water can be accelerated is very much greater. This can be illustrated as follows: Water will flow from a tank through an orifice discharging into the open air at a velocity depending upon the depth of the orifice below the surface of the water in the tank.

It will flow through the same orifice into the exhausted receiver of an air pump at a much higher velocity, depending upon the degree of exhaustion in the receiver. The velocity in the latter case will be that due to the head of the water plus the difference between the pressure of the atmosphere and that in the exhausted receiver. Similarly, the velocity with which water

can be made to flow towards a submerged screw is due to the head of water over the screw plus the atmospheric pressure, and there is consequently a definite limit to the speed to which it can attain.

It was not easy to calculate theoretically at what point the breakdown would occur with a given propeller, but a way of attacking the problem suggested by Mr. Thornycroft proved to greatly simplify it, and to render its solution possible. His idea was that there must be a definite thrust per sq. inch of projected screw surface at which cavitation commenced.

A screw propels by putting water in motion sternwards. It effects its object partly by pushing the water with the after face of the blades, and partly by pulling it with the forward face. Imagine that we have replaced the screw of a ship by a disc of rather less diameter than the screw, and that, instead of revolving the screw shaft, we push the shaft and disc sternwards at such a speed that the momentum of the water moved by the disc is equal to the sternward momentum of the water put in motion by the screw. The propelling effect would be the same as that of the screw, or nearly so if the movement is confined to the length of the screw, and so far as the action between the forward face of the screw blades and the contiguous water is concerned, which is what I wish to illustrate, the action of the disc affords a sufficiently close analogy. As the disc moves sternwards, it puts water in motion not only astern of it but also ahead of it. There being no air ahead of the water and the front face of the disc, a pull can be exerted upon the water, which is forced to follow the disc in the same manner that water is forced to follow the plunger of a pump.

But the pull which can be thus exerted by the disc is limited. At a little beneath the surface of the water, if the tension exceeds 15 pounds per square inch (one atmosphere), the surfaces of the disc and adjacent water are torn asunder, and the cavity is formed between them.

As but a little more than half of the total acceleration imparted to the water by a screw is estimated to be produced by the suction of the forward surface, it might be supposed that a total thrust approaching to 30 pounds per square inch (two atmospheres) might be obtained, but it appears that rupture occurs at parts of the screw surface long before the mean thrust per

square inch of the whole surface reaches this amount. This is probably accounted for by the fact that the thrust of portions of the screw blade near the circumference is much greater than at portions near the boss.

By plotting the results of a progressive trial carried beyond the speed at which cavitation commenced, we were able to note the point at which the first indication of failure appeared. It is not marked by a sudden change, but by a flexure in the curve of slip, which commences to rise rapidly when the critical speed is reached.

The total thrust of the screw at this speed, divided by its projected blade area, gave a thrust of 11¼ pounds per square inch (0.75 atmosphere), which is, therefore, about the maximum thrust which can be obtained from a screw working efficiently at a depth below the surface of 11 inches, which was the immersion of the tips of the blades in the Daring. The figure should vary slightly with the pitch ratio, being less if the latter is high, since the ratio which the suction thrust bears to the whole thrust varies with the pitch ratio, but the variation is so small as to be negligible. For every additional foot of immersion, the total thrust per square inch may be increased by ⅜ of a pound.

PROBLEMS.—(P. 301, S. & O.)

80. The following data are from trials of the U. S. S. Yorktown:

Speed in knots per hour.	I. H. P.	Revolutions per minute.	Displacement.
16.62	3570	161	1700 tons.
14.78	2325	140	1700 tons.

Required the I. H. P. and the number of revolutions per minute to drive this ship at a speed of 10 knots.

81. How many revolutions and what I. H. P. would be required to drive the Yorktown 18 knots per hour?

82. The design of the New York is for a speed of 20 knots with 16,500 I. H. P., and a displacement of 8150 tons.

What I. H. P. would this ship require to drive it 21 knots?

Keeping the same I. H. P., what amount of weight must be removed so that it will make 22 knots?

83. A 400-ton ship has a maximum speed of 10 knots. Sup-

pose that it take on board 100 tons of coal, what speed can then be made?

84. If at the maximum speed of the Yorktown (see Prob. 80), 2.3 pounds of coal per I. H. P. per hour is required, and at 10 knots per hour only 1.8 pounds, what distance can be covered on a coal supply of 100 tons at the maximum and at the reduced speeds?

85. A ship whose displacement is 400 tons makes 10 knots with 300 I. H. P.

How much would it be necessary to lighten the ship so that with the same I. H. P. it may make 11 knots?

86. What is the most economical speed for a steamer steaming against a current running a knots per hour?

SOLUTION OF QUESTION 86.

Let C = Coal consumed per day or hour.

x = Speed of the ship through the water.

$x - a$ = Speed of the ship over the ground.

$\frac{C}{x-a}$ = Cost in coal per knot over the ground.

Making this a minimum will give the most economical speed against the current.

The coal expended varies as the *cube of the speed*, since this amount is nearly proportional to the I. H. P. Therefore:

Let $C = Kx^3$; where K is a constant. Then

$\frac{C}{x-a} = \frac{Kx^3}{x-a}$. Differentiate this equation, and we find:

$$\frac{K[3x^2(x-a) - x^3]dx}{(x-a)^2} = 0. \quad \text{Solving}$$

$$x = \tfrac{3}{2}a.$$

EXPLANATION OF THE METHOD OF COMPLETING THE CURVE OF INDICATED THRUST.

Art. 23.—(P. 304, S. & O.)

"The curve, as fixed by the data, terminates at some moderate speed; say 3, 4 or 5 knots. It is known that with tolerably well shaped ships the resistance due to such moderate speeds as

these consists almost solely of surface friction; which, as experiments have shown, varies nearly as the 1.87 power of the speed, with perhaps a very small residue, or excess of resistance, apparently proportional to the square of the speed. As this residue is very small indeed, we may assume that the whole resistance, below 3 or 4 knots, is as the power 1.87 of the speed."—(W. Froude. Transactions of the Institute of Naval Architects, Vol. XVII., 1876, p. 170.)

Equation to curve is $y = ax^{1.87} + c$ (1)

Let x_1 and y_1 be coordinates of P, then

$$y_0 = c = y_1 - ax_1^{1.87} \quad (2)$$

Differentiating (1), $\frac{dy}{dx} = 1.87\ ax^{0.87}$.

Equation to tangent at P is

$$y - y_1 = 1.87\ ax^{0.87}(x - x_1) \quad (3)$$

In (3) let $y = c = y_0$, then

$$y_1 - ax_1^{1.87} - y_1 = 1.87\ ax^{0.87}(x - x_1),$$

$$\text{from which } x = \frac{0.87x_1}{1.87}$$

$$\text{or, } \frac{OR'}{OQ} = \frac{0.87}{1.87}.$$

ART. 24.—(P. 338, S. & O.)

The main points of construction of the indicators shown in Figs. 26 and 27 are almost the same as those described on pages 336-338 of Sennett and Oram.

A set of indicators is always supplied to the ships of our navy, and reducing gears are fitted to each cylinder, so that the indicator has only to be carefully and correctly placed on the indicator cock, the string attached and the card from each end of the cylinder taken.

Before attaching the indicator, which is kept in its box in the storeroom, take the caps off the indicator cocks on the cylinder and blow steam through to clear and warm up the cocks and connecting pipes.

Place the taper nozzle in the mouth of the cock and set up on the jam nut and attach the indicator firmly with the cord pulley

leading fair to the point of attachment on the reducing motion.

A strong inelastic cord, with an attached hook, is wound around the bottom of the paper drum, and as the drum is revolved, by this cord, it should not come up against its stops. When certain that this is the case and that everything is working smoothly, stop the drum with the pawl, bend the indicator card around the top of the drum and, holding the ends together, slip them down between the clips, leaving the surface of the card smooth and the ends square.

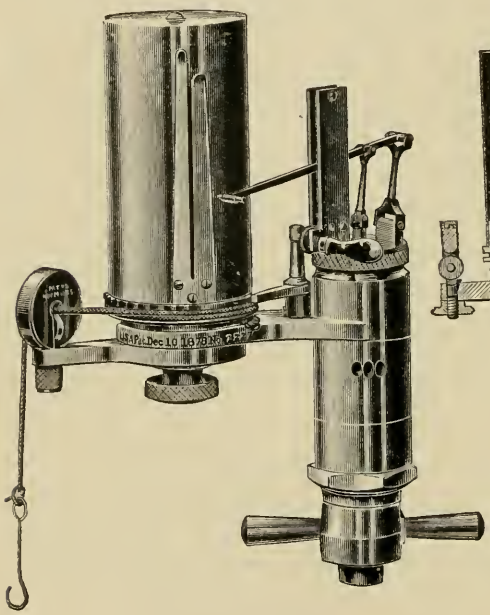


Fig. 26.—Indicator.

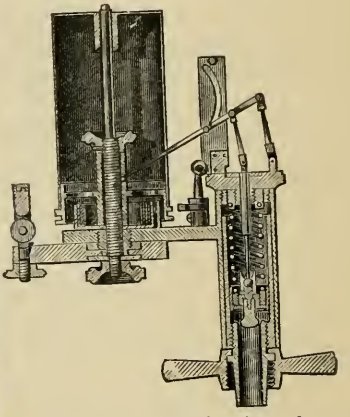


Fig. 27.—Section of Indicator.

Turn steam on slowly, to warm up the indicator and blow it free of water, and when this is done shut off the steam and let the pencil trace the atmospheric line on the card. Turn the steam on full and bring the pencil point lightly against the card, tracing a light single line during one revolution of the engine. Do this for each end of the cylinder, then remove the card and write the required data on the blank spaces on its back.

When cards have been taken from all the cylinders, remove the indicators, wipe them dry and clean, then oil the pistons and

replace in the indicator boxes. Screw the caps on the cocks and see that all the valves are closed.

Figs. 28 and 29 show the back and front of the indicator card complete and ready to be filed away or sent on to the Department with the quarterly returns.

NOTE.

To find the Mean Effective Pressure of a Theoretical Indicator Card having Compression and Clearance.

Art. 25.—(P. 344, S. & O.)

It is assumed that both the expansion and compression curves follow the law $pv =$ a constant.

A, B, C, D, represent the areas shown in the figure; and a, b, c, d, e, f, g, the lengths as shown on the theoretical card.

$p_e =$ the mean effective pressure $=$ the mean ordinate of the area A.

$$p_e = \frac{A}{c} = \frac{(A + B + C + D) - B - C - D}{c}. \qquad (1)$$

From a previous note (Art. 17), we can find the area $(A + B + C + D)$ and also that of B from the equation deduced in that note:

$$\text{Area} = p_1 \times \frac{(1 + \text{hyp. log. } r)}{r} \times \text{the length of the area.} \qquad (2)$$

In $(A + B + C + D)$ we have, from the figure, $p_1 = e$; and $r = \frac{a + c}{a + b}$, and by the figure also, the length of the area $= a + c$.

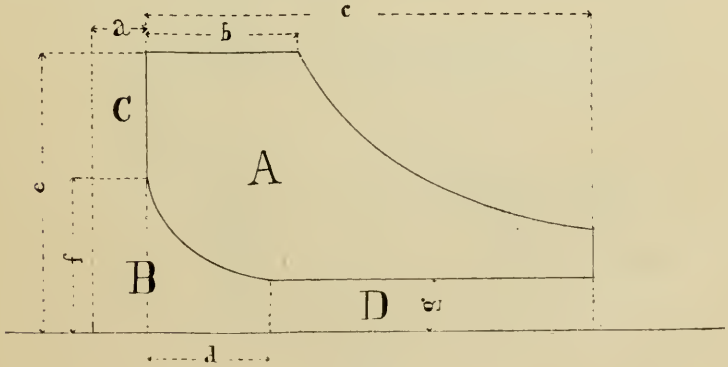


Fig. 30.

BUREAU OF ST. ENG'R'G.
FORM NO. 50 D.

CARD NO. 1.

This must be filled in on all diagrams.

U. S. S. Columbia

Date and hour, Nov. 18, 1893, 2.10 P.M.

Which engine, Starboard.

Which cylinder and which end, H.P. Both Ends

Revolutions per minute, 134.

Steam pressure in boilers, by gauge, in lbs., 147.2

" " at engine, " " 145.

" " in First receiver, in lbs., above a perfect vacuum, 75.

Steam cut-off at 6 of the stroke from the beginning by —

Position of link, Ahead

Opening of throttle-valve, in holes, 10.

Vacuum, in inches of mercury, 25.

Indicated horse power of this diagram, 1922.17

" " " of this cylinder, 1922.17

Collective I. H. P. of engine, 6605.84

Horse power (Est.) of aux. machinery in use, 518.13

Square feet of heating surface in use, 43311.06

Square feet of grate surface in use, 1408

Pounds of coal (Bitum.), net weight, consumed per hour, 39979

Speed per hour, in knots and tenths, 22.8

Sails set, none

Wind. Points from ahead, 2 Force, 2

Sea. " " " , S Kind, —

Barometer, 29.78 Attached thermometer, 84°

Temperature of injection water, 49°

" " discharge water, 134°.2

" " feed water, 109°.3

Draught of Vessel (measured at the time, if possible; otherwise, estimated.) Forward, 21'-3"

Aft, 23'-8"

Slip of Propeller, 19.82 %

4—162

Fig. 28.—Front of Indicator Card.

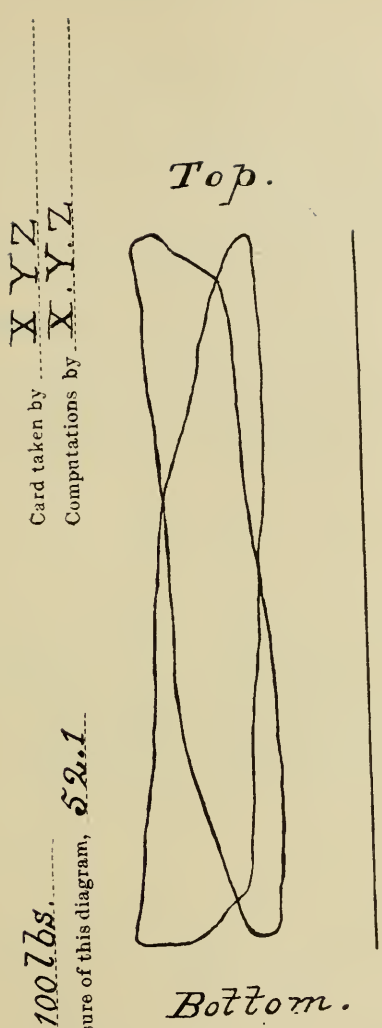


Fig. 29.—Back of Indicator Card.

Similarly, in the case of B, we have from the figure:

$$p_1 = f, \quad r = \frac{a+d}{a}, \text{ and the length of the area} = a + d.$$

Making these substitutions in (2) we find the area $(A + B + C + D)$ and also that of B.

C and D are rectangles and their areas equal their lengths $\times$ their breadths.

Substituting in (1), p_e is found.

NOTE:—In solving problems like this, first draw the theoretical indicator card as above, and place all the known quantities upon it.

Then by means of the equation, $pv =$ a constant, find the quantities not given and proceed as shown.

EXAMPLE.

Stroke of the engine $= 42''$. Cut-off is at $9''$ from the beginning of the stroke. Clearance, reduced to equivalent length of cylinder, is $4''$. Initial pressure $= 100$ pounds. Compression begins $6''$ from the end of the stroke. Back pressure before the compression begins $= 15$ pounds absolute.

Find the mean effective pressure on the piston of the engine.

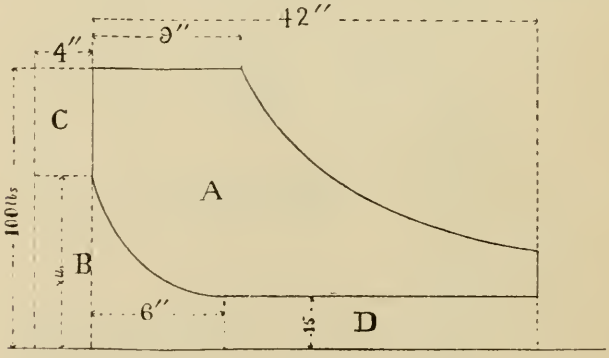


Fig. 31.

$$D = 15\,(42 - 6) = 540.$$
$$C = 4\,(100 - 37.5) = 250.$$

Then, in B, since $p_x v_x = p_{15} v_{15}$

$$x \times 4 = 10 \times 15, \quad \therefore x = 37.5.$$

$$(A + B + C + D) = 100 \times \frac{\left\{1 + \text{hyp. log.} \left(\frac{42 + 4}{9 + 4}\right)\right\}}{\frac{42 + 4}{9 + 4}} (42 + 4)$$

$$= 100 \times 46 \times .642 = 2953.2,$$

$$B = 37.5 \times \frac{\left\{1 + \text{hyp. log.} \left(\frac{6 + 4}{4}\right)\right\}}{\frac{6 + 4}{4}} (6 + 4)$$

$$= 37.5 \times 10 \times .766 = 287.25.$$

Consequently:

$$p_e = \frac{A}{c} = \frac{2953.2 - (287.25 + 250 + 540)}{42} = 44.6 .$$

Problems.

87. Stroke of engine = 34″. Initial pressure = 175 pounds per square inch. Final pressure = 10 pounds per square inch. Back pressure = 3 pounds per square inch. Clearance = 1″. Final pressure of compression = 12 pounds per square inch. Area of the piston = 200 square inches. Engine makes 150 revolutions per minute.

Find the I. H. P. of the engine. *Ans.* 161.97 I. H. P.

88. Supposing that all the data of the preceding question remain the same except that the stroke be changed to 40″.

Find the I. H. P. *Ans.* 194.4 I. H. P.

89. Stroke of engine = 8″. Diameter of the cylinder = 10″. Initial pressure of the steam = 160 pounds per gauge. Ratio of expansion = 12. Back pressure = 8 pounds per square inch. Clearance = .4″. Compression to begin at the middle of the stroke. Engine makes 250 revolutions per minute.

Find the I. H. P. *Ans.* 23.785 I. H. P.

90. Supposing that all the data of the previous question remain the same except that the initial pressure be 100 pounds absolute, instead of per gauge.

Find the I. H. P., and the consequent change in the number of revolutions per minute that would necessarily follow.

Ans. I. H. P. = 5.208; Revolutions = 150.7.

91. Find the gain in I. H. P., if the engine of question 89 has a back pressure of 3 pounds instead of as there given.

How many heat units does this represent?

If the feed-water be taken from the *hot-well*, how much has it been cooled?

Is there any gain then in carrying the vacuum lower?

The temperatures of steam of 8 pounds and 3 pounds are 182.92°, and 141.62° respectively.

Ans. Gain = 11.46 I H. P.

92. Stroke of the engine = 33″. Clearance = 7 per cent. of the piston displacement. Initial pressure = 180 pounds absolute. Final pressure = 15 pounds. Final pressure of compression = 50 pounds. Compression to continue for ⅔ of the stroke. Diameter of the piston = 40″. Revolutions per minute = 150.

Find the I. H. P. *Ans.* 1050 I. H. P.

93. If the clearance of the engine of the previous question be changed so that it is twice as large, and the point of cut-off remain the same, what will then be the I. H. P.?

Ans. 1610 I. H. P.

94. If the stroke of the engine of question 92 be made 40″; the other data remaining the same, what will then be the I. H. P.?

95. Suppose that, in question 92, the final pressure of compression = the initial pressure.

Find the I. H. P.

NOTE.

Water per I. H. P. per Hour Accounted for by the Indicator Card.

Art. 26.—(P. 352, S. & O.

The weight of steam in the cylinder, at any instant, can be found by dividing the volume, occupied by it at the given time, by the *specific volume* of the steam for the pressure in the cylinder.

The pressure is taken from the card and the specific volume is either taken from the tables or calculated by the equation $pv^{\frac{17}{16}} = 475$.

It is evident that if there be no *condensation* or *re-evaporation*, the weight, so calculated, would be the same for all points of the expansion curve, and that the same would also be true for the compression curve.

The weight of steam used by the engine per stroke would then be the difference between the weights calculated for the pressures given by the two curves. The first quantity is the steam in the cylinder at the end of the stroke and the second quantity the amount of compressed steam that is retained in the cylinder and which does not go to the condenser.

This difference of weight per stroke being multiplied by the number of strokes per hour and divided by the I. H. P. developed gives the number of *pounds of water used per I. H. P. per hour*, as accounted for by the indicator.

In the *theoretical card*, the only points that we know in the curve are those of *cut-off* and *exhaust closure*, and these would be the points which we would have to use.

In an actual card, however, any points of the curve may be used.

Example.

Find the number of pounds of water per I. H. P. per hour accounted for by the indicator, which is used by an engine, the theoretical card and other data of which are in the Example preceding Problem 87.

The area of the piston = 1000 square inches, and the number of revolutions per minute = 50.

(1) At cut-off, the steam occupies a volume $= \frac{(9+4) \times 1000}{1728}$ cubic feet.

The specific volume of the steam as calculated above, or as taken from the tables, for an initial pressure of 100 pounds per square inch = 4.4 cubic feet.

(2) Consequently the weight of the steam at cut-off

$$= \frac{(9+4) \times 1000}{1728 \times 4.4} \text{ pounds.}$$

Similarly the weight of steam in the cylinder at exhaust closure $= \frac{(6+4) \times 1000}{1728 \times 26.15}$ pounds, the specific volume for steam of 15 pounds pressure being 26.15 cubic feet.

(3) The difference between (1) and (2) $= \frac{1000}{1728}\left\{\frac{(9+4)}{4.4} - \frac{(6+4)}{26.15}\right\}$ is the weight of steam used per stroke, or, expressing the same thing differently, it is the amount of steam which the cylinder empties into the condenser at each stroke, and the amount which is not emptied is that retained for compression; this helps fill the cylinder when the fresh steam comes from the boiler for the next stroke.

(4) The weight of steam used per hour $= (3) \times 2 \times 50 \times 60$.

(5) I. H. P. $= \frac{\left(44.6 \times \frac{42}{12} \times 1000 \times 2 \times 50\right)}{33000}$.

(6) Therefore $\frac{(4)}{(5)} =$ *the number of pounds of water per I. H. P per hour* used by the given engine, as *accounted for by the indicator* and calculated from the theoretical indicator card.

METHOD WHEN USING AN ACTUAL INDICATOR CARD.

Art. 27.—If an actual card be used, and a line, such as *ab*, be drawn, above the points of *release* and *compression* and below *admission*, parallel to the atmospheric line, cutting both the ex-

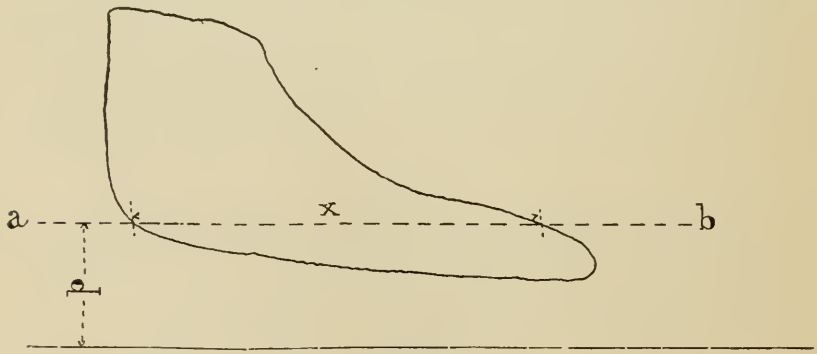


Fig. 32.

pansion and compression lines as shown; then letting the length in inches of the intercept of the line *ab* by the curves be x; the area of the card be A square inches; the specific volume be v, corresponding to the pressure p at the line *ab*; s be the scale of

the indicator spring; l be the length of the card in inches; V be the volume of piston displacement in cubic feet, and N be the number of revolutions of the engine per minute.

$$\text{The total water per hour} = \frac{x}{l} \times \frac{V}{v} \times 60 \times 2N \qquad (1)$$

$$\text{The I. H. P. of the cylinder} = \frac{\frac{A}{l} \times s \times 144V \times 2N}{33000}. \qquad (2)$$

Dividing (1) by (2), we have water per I. H. P., per hour =

$$\frac{13750 \times x}{sAv}$$

This formula gives the water per I. H. P. per hour if the card is from a simple engine. If from one cylinder of a multiple expansion engine, the result should be multiplied by

$$\frac{\text{I. H. P. of cylinder}}{\text{I. H. P. of engine}}$$

Problems.

96. Find the *number of pounds of water per I. H. P. per hour* used by the engine of Problem 87.

97. Find the same for Problem 88.

98. " " " " " 89.

99. " " " " " 90.

100. " " " " " 91.

101. " " " " " 92.

102. " " " " " 93.

103. " " " " " 94.

104. " " " " " 95.

105. Find the I. H. P. from the following cards and data:

Diameter of cylinder = 36″. Scale of indicator spring 30 pounds = 1″.

Stroke of engine = 3′.

Revolutions per minute = 40.

Find the *mean effective pressure* and the *I. H. P.* for each stroke separately.

106. Find the number of pounds of water necessary to be evaporated per hour in order to supply the engine of Problem 105 with steam to develop the power calculated.

107. Find the *cut-off* on the inboard and outboard strokes respectively, in inches from the beginning of the stroke, of the engine of Problem 105.

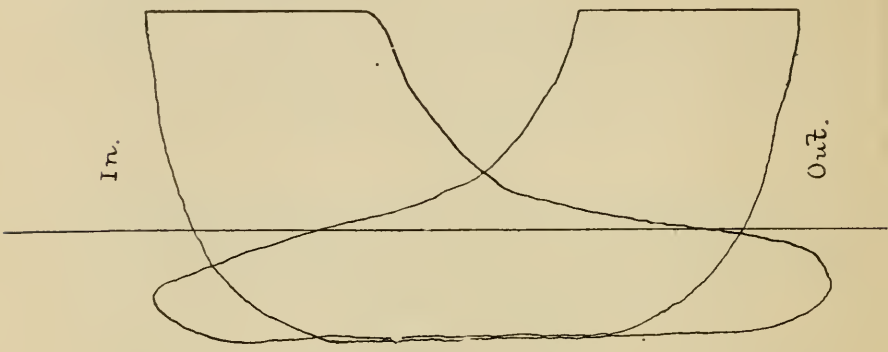


Fig. 33.

108. Determine the amount of *condensation* or *re-evaporation*, if there be any, in the engine of Problem 105 during the inboard stroke, supposing that the steam were *initially dry and saturated.*

109. Supposing that the steam contains 10 per cent. of moisture when it is received in the cylinder; find the number of pounds of water required per I. H. P. per hour for the engine of Problem 105.

110. Find the I. H. P. from the following cards and data:
Scale of indicator spring = 20 pounds to the inch.
Diameter of the cylinder = 90″.
Stroke of the engine = 40″.

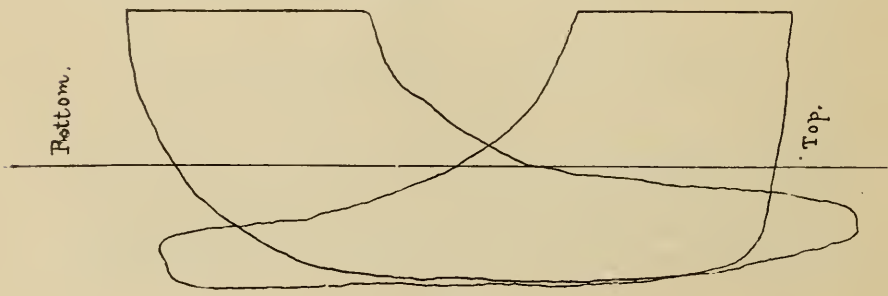


Fig. 34.

Revolutions per minute are sufficient to produce a mean piston speed of 800 feet per minute.

111. Find the water required per I. H. P. per hour in the engine of Problem 110.

112. Find the number of pounds of water that must be evaporated per hour to supply the engine of Problem 111 with steam, supposing that the steam contains initially 5 per cent. of moisture.

THE MACOMB STRAINER.

Art. 28.—(P. 371, S. & O.)

It is necessary to fit the *bilge suction pipes* of all pumps with strainers to catch anything which would *choke* the pipes and valves of the pump if permitted to enter.

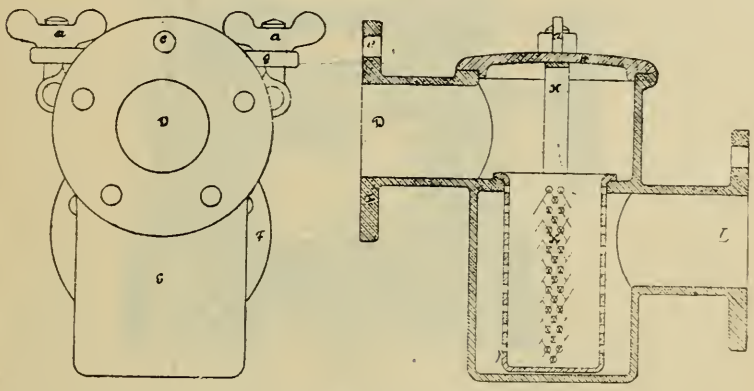


Fig. 35.—Macomb Strainer.

The *Macomb strainer*, shown in Fig. 35, has been used for many years in the ships of our navy. The pump suction is attached to the flange *L*, the pipe to the bilge leads from the flanged nozzle *D*. A copper basket *K* rests on an interior flange in the chamber and all water entering the pump must be strained through the holes in this basket.

At intervals the *wing nuts* are unscrewed and the cover *g* removed. The basket *K* is then lifted out by the handle *H* and a spare basket put in place of *K*. *K* is then cleaned ready for use to replace the spare basket when choked. All of the coarser dirt is thus trapped in the basket.

ASH HOISTING ENGINE.

Art. 29 (P. 387, S. & O.)

Fig. 36 is one form of the "Williamson" ash-hoist, which is used in our navy. It consists of a two-cylinder engine, with overhung cranks, driving the hoisting drum; each engine having a single eccentric to work its slide-valve.

The ash buckets are raised or lowered by working the engine, by means of the hand wheel shown on the left of the figure, which is kept moving in the direction it is desired that the drum revolve; thus keeping open a reversing valve (similar to the one shown in Fig. 181 of Sennett & Oram) which controls the supply and direction of the steam for the two engines. When the movement

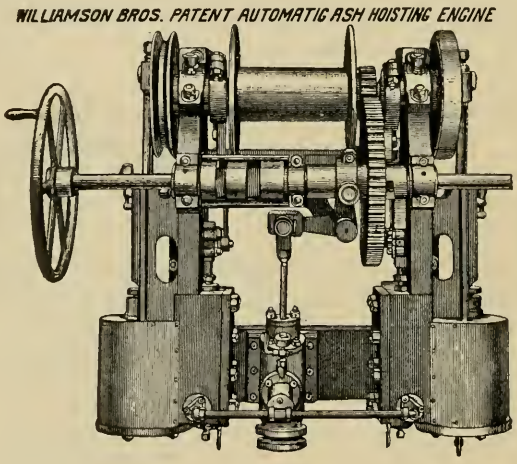
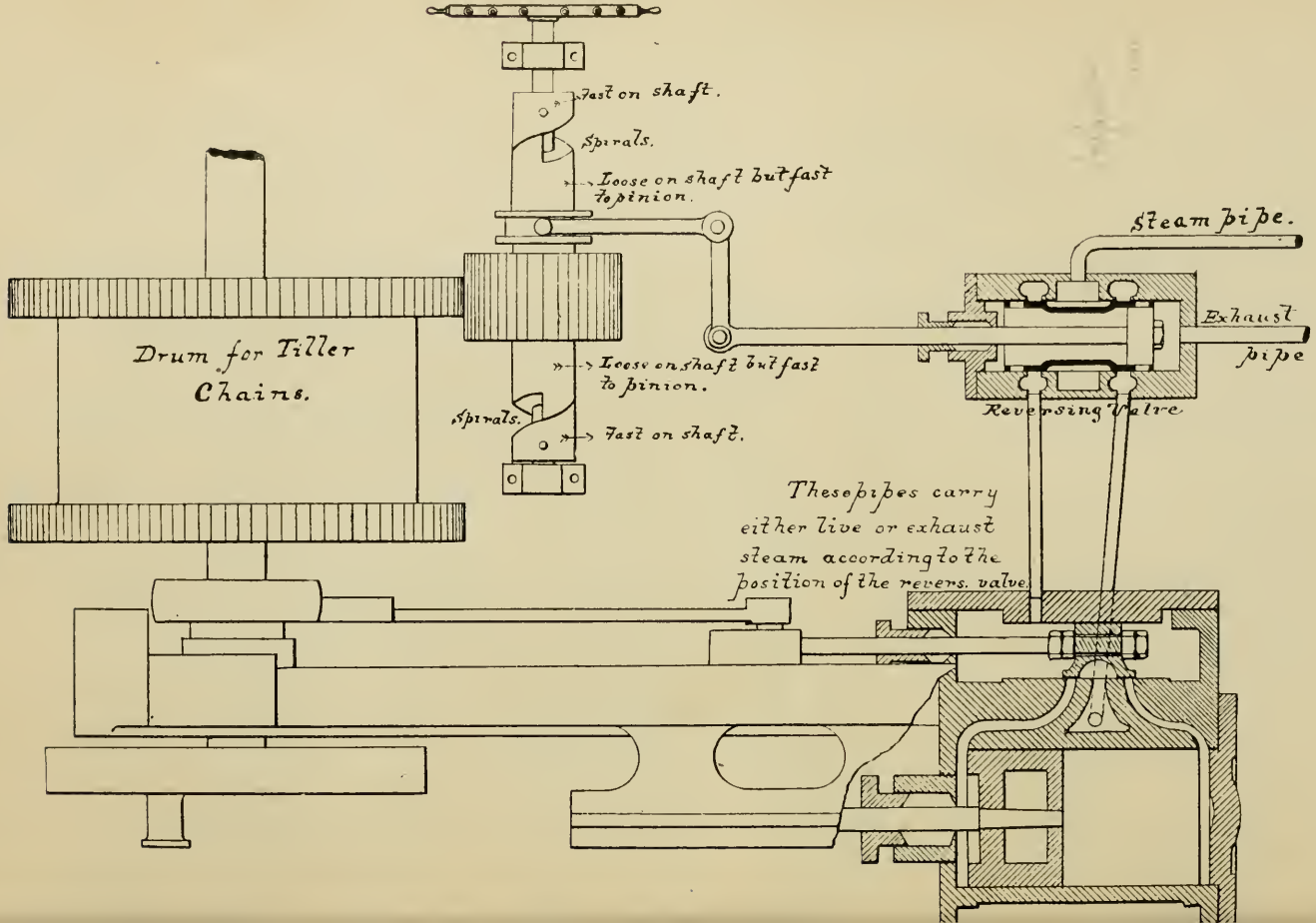


Fig. 36.

of the hand wheel ceases, a further small movement of the engines closes the reversing valve and the supply of steam is shut off from the cylinders.

Fig. 37 illustrates this valve motion. A long pinion, cast with sleeves extending on either side, fitted loose on the "automatic" or hand-wheel shaft, is free to move axially on the shaft for a short distance. This pinion gears into a spur wheel secured to the drum shaft. On one side of the pinion a groove is cut into the sleeve, and in this groove is fitted a loose collar or strap, which, through a bell-crank, moves the reversing valve when the pinion is moved either to the right or left, thus reversing the flow


Fast on shaft.
Spirals.
Loose on shaft but fast to pinion.
Drum for Tiller Chains.
Loose on shaft but fast to pinion.
Spirals.
Fast on shaft.
Steam pipe.
Exhaust pipe
Reversing Valve
These pipes carry either live or exhaust steam according to the position of the revers. valve.

of steam through the pipes leading to the valve chests on the cylinders. At each end, the pinion sleeve has a spiral face cut on it, which works against a similar spiral cut on blocks that are secured to the shaft; so that, when the hand wheel and its shaft are revolved in either direction, the spiral faces force the pinion to move along the shaft, so opening the reversing valve, but leaves it still in gear with the spur wheel on the drum shaft; which, on the starting of the engines, tends to move the pinion in the opposite direction along the shaft, so bringing it back to the central position where the reversing valve is closed.

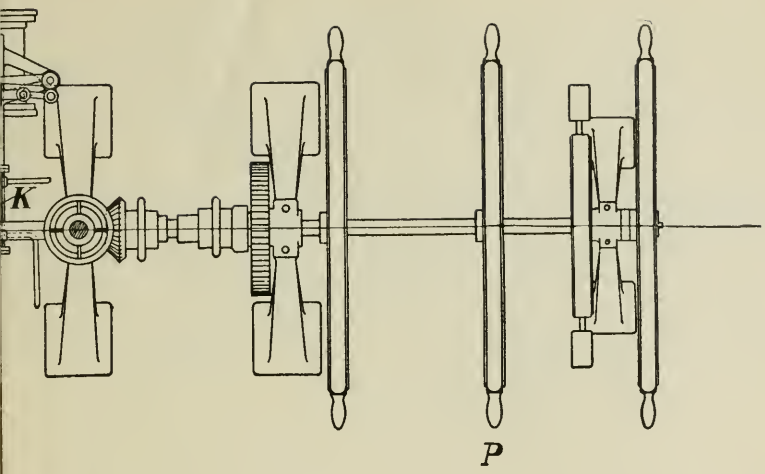
Therefore, as long as the hand wheel is turned, the engines follow it; but, as soon as the motion of the hand wheel ceases, the pinion will catch up and the engine stops.

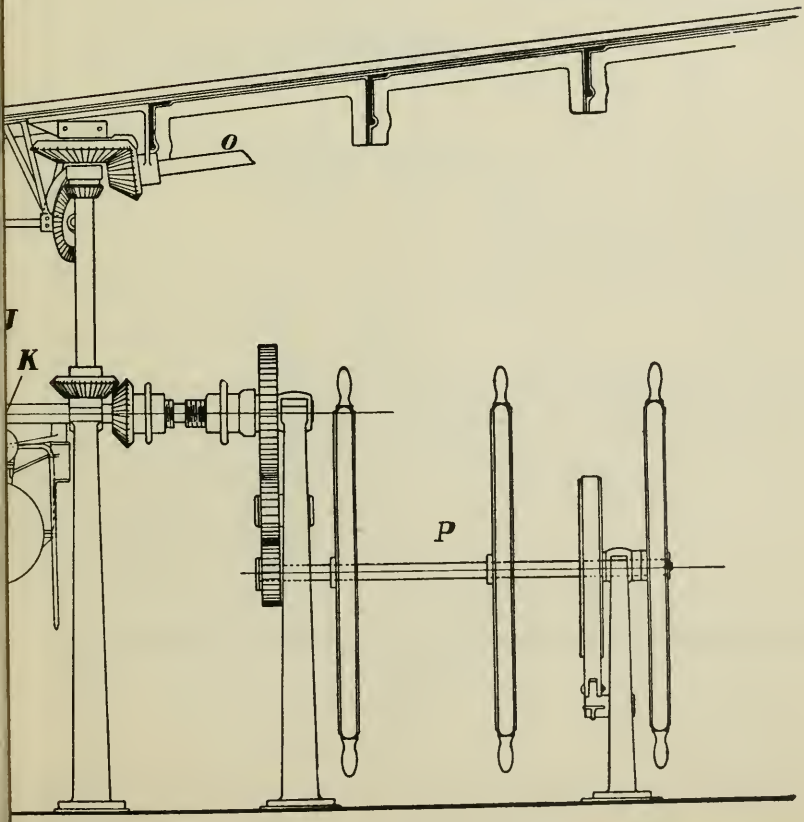
Safety stops are put on to prevent the pinion being moved too far along the automatic shaft.

The screw thread shown in Fig. 36, on the automatic shaft, carries a nut which is prevented from turning, but is allowed sufficient lateral motion between stops to give the proper amount of hoist. On bringing up on the stops, it prevents the bucket being raised or lowered too far, and thus avoids danger of breaking the rope.

STEAM STEERING ENGINE.

Art. 30 (P. 372, S. & O.).—Fig. 38 shows a steering engine as applied to one of our large cruisers or battle-ships, which has the same valve motion as the ash-hoist described in the preceding article. The automatic shaft is shown at *L* in the plan: *N* shows one of the steam cylinders and a pointer below that letter shows a rudder tell-tale, which is used when the steering engine is tried or worked by means of the hand wheel *I; H* is the steering engine crank shaft (the letter *H* being placed below the shaft on the plan and above it on the elevation); which carries a spur wheel that gears into the large spur wheel (which also carries the small spur wheel abaft it that gears into the pinion on the automatic shaft *L*) fitted loose on the shaft *G*, but to which it can be secured by the clutch *M*. The shaft *G* extends from the wheels *P* to the bearing just forward of the rudder head; the after part of *G* is threaded with a right and left hand screw thread on which work driving nuts, kept in line by side rod guides. The driving nuts


K
P


o
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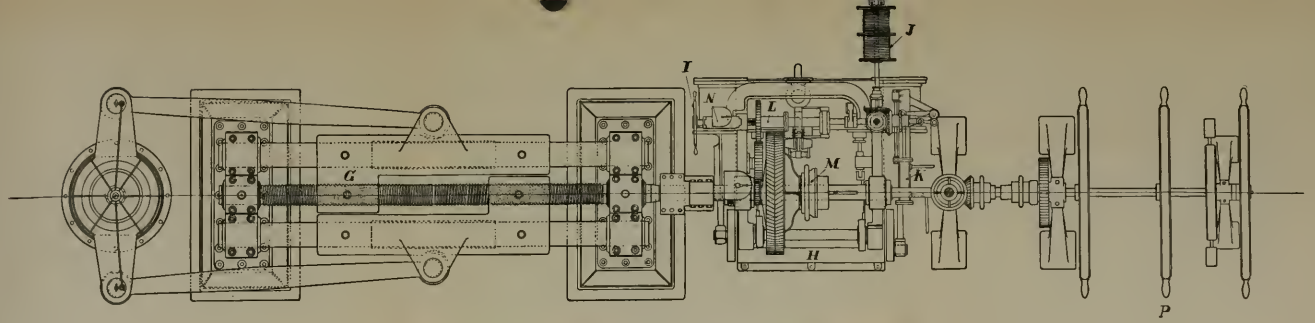


WILLIAMSON BROS.-PATENT-STEERING-GEAR.

AS APPLIED TO THE

MODERN BATTLE-SHIPS

OF THE

UNITED STATES NAVY.

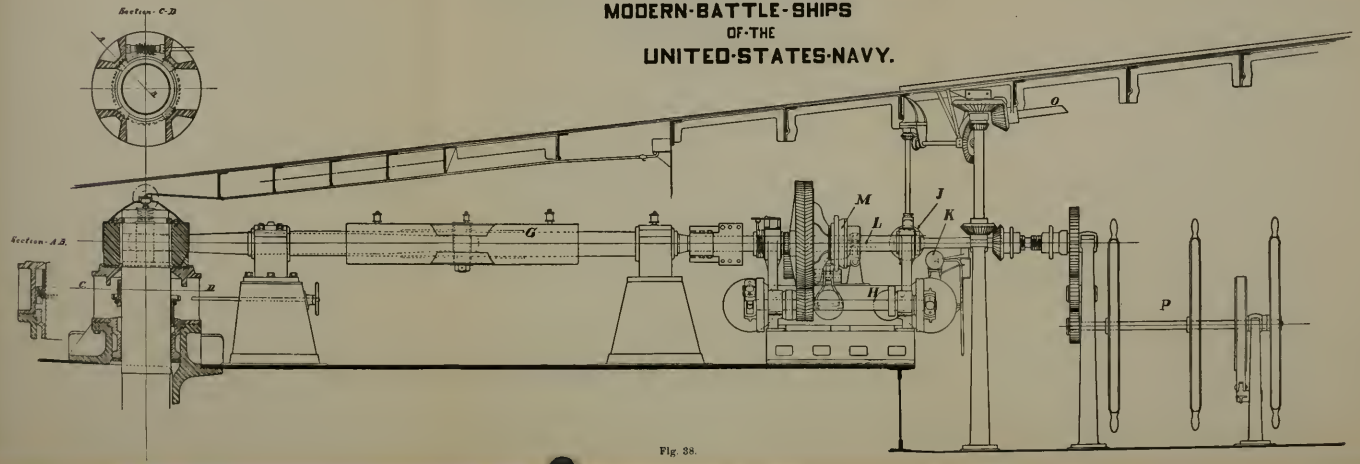


Fig. 38.

move in opposite directions and are each connected to its end of the yoke on the rudder head by means of connecting rods.

The vessel can be steered by steam: *first*, by means of the hydraulic *telemotor K*, which works the shaft *L* through bell-cranks; *second*, by means of motion given to the drum *J* through a rope leading from the steering wheel in the conning tower, on the bridge or other deck station, which motion is conveyed to *L* by the bevel gears shown in the plan; *third*, by motion received through the shaft *O*, which is connected by shafting and gearing to a wheel on deck, and which can be connected to *L*, through the smaller vertical shaft and the gearing shown in elevation over the letters *J* and *K; fourth*, through the wheel *I*, which is also used for trying the engine before getting underway.

The vessel can be steered by hand power: *first*, by means of the shaft *O*, which can be geared to *G* through the larger vertical shaft shown in the elevation; *second*, through the wheels *P*, located in the steering engine room, which can be thrown into gear by means of the coupling shown on the forward end of *G*. In either of the above methods of steering by hand power, the clutch *M* must be thrown out of gear, so that *G* can revolve without moving the spur wheels and engines, or giving motion to *L*.

To use one of the above methods of steering, either by steam or hand power, its particular clutch must be put in gear, and the clutches for the other five methods thrown out of gear.

Also, a long tiller is fitted above the yoke on the rudder head, to the forward end of which side tackles can be hooked, and the vessel steered by this means. If the vessel is steered by the tiller, the connecting rods must be disconnected from the yoke on the rudder head.

There is a working model of a Williamson steering engine in the Department of Seamanship.

DISTILLING APPARATUS IN THE U. S. NAVY.

Art. 31 (P. 400, S. & O.).—On U. S. vessels the term *condenser* is applied to the apparatus used to condense the exhaust steam from the engines, while the apparatus used for making potable fresh water is usually called a *distiller*.

Fig. 39 shows the type of distiller fitted on the latest of our naval vessels. The shell is of cast iron and the tube sheets of composition. Where it is possible the shell stands upright, the

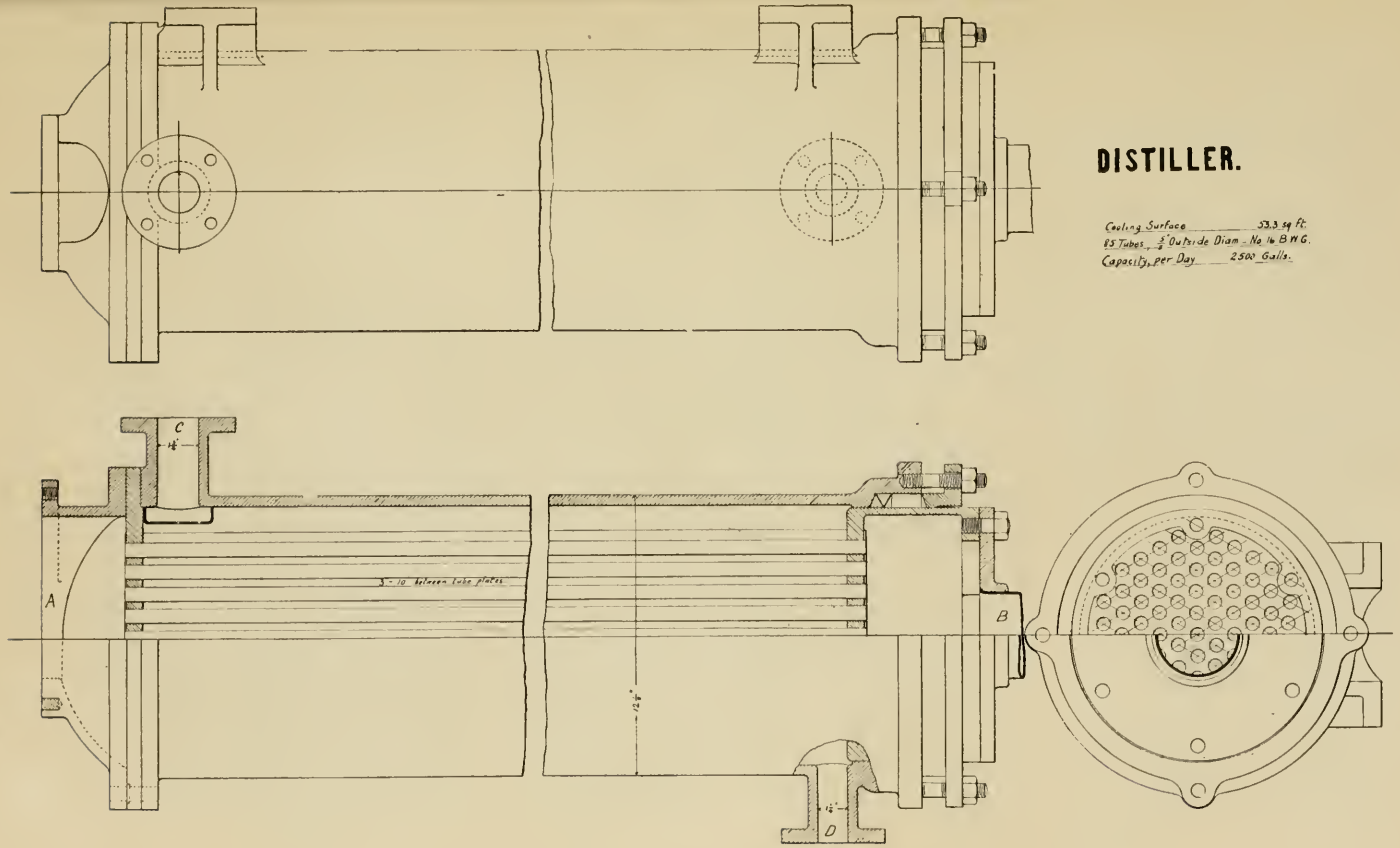

DISTILLER.
Cooling Surface 53.3 sq ft.
85 Tubes, 5/8" Outside Diam - No 14 B.W.G.
Capacity per Day 2500 Galls.
C
4"
A
5 - 10 between Tube plates
B
D
4"

Fig. 39.

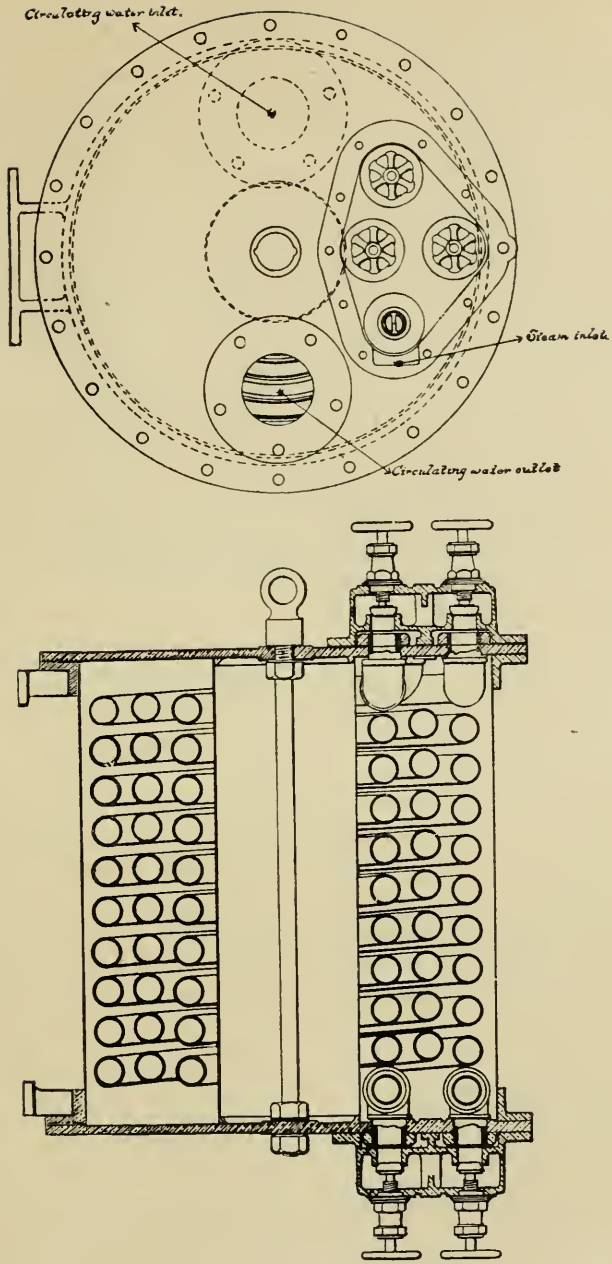


Fig. 40.—Baird's Distiller.

end *A* being on top. If placed horizontally, the side *C* is on top. The tubes are ordinary condenser tubes, 5/8" outside diameter, No. 16 wire gauge. They are expanded into the tube sheets, the lower tube sheet being arranged to slide in a stuffing box to allow for the expansion of the tubes.

The condensing water enters at *B* and flows out at *A*. Steam from the evaporator enters at *C* and the condensed fresh water is drawn off at *D*. The perforated diaphragm under *C* is for the purpose of distributing the entering steam over a wider area and thus preventing injury to the tubes at the entrance.

Fig. 40 shows a type of Baird's distiller, which is on many of our older vessels. It consists of a copper or composition shell in which are coiled tinned copper tubes, each of which passes at top and bottom into the chambers where valves, arranged as shown, enable each coil to be shut off independently of the others. This feature is useful in case of a leaky coil, enabling the defective coil to be located and shut off, the others still remaining in use.

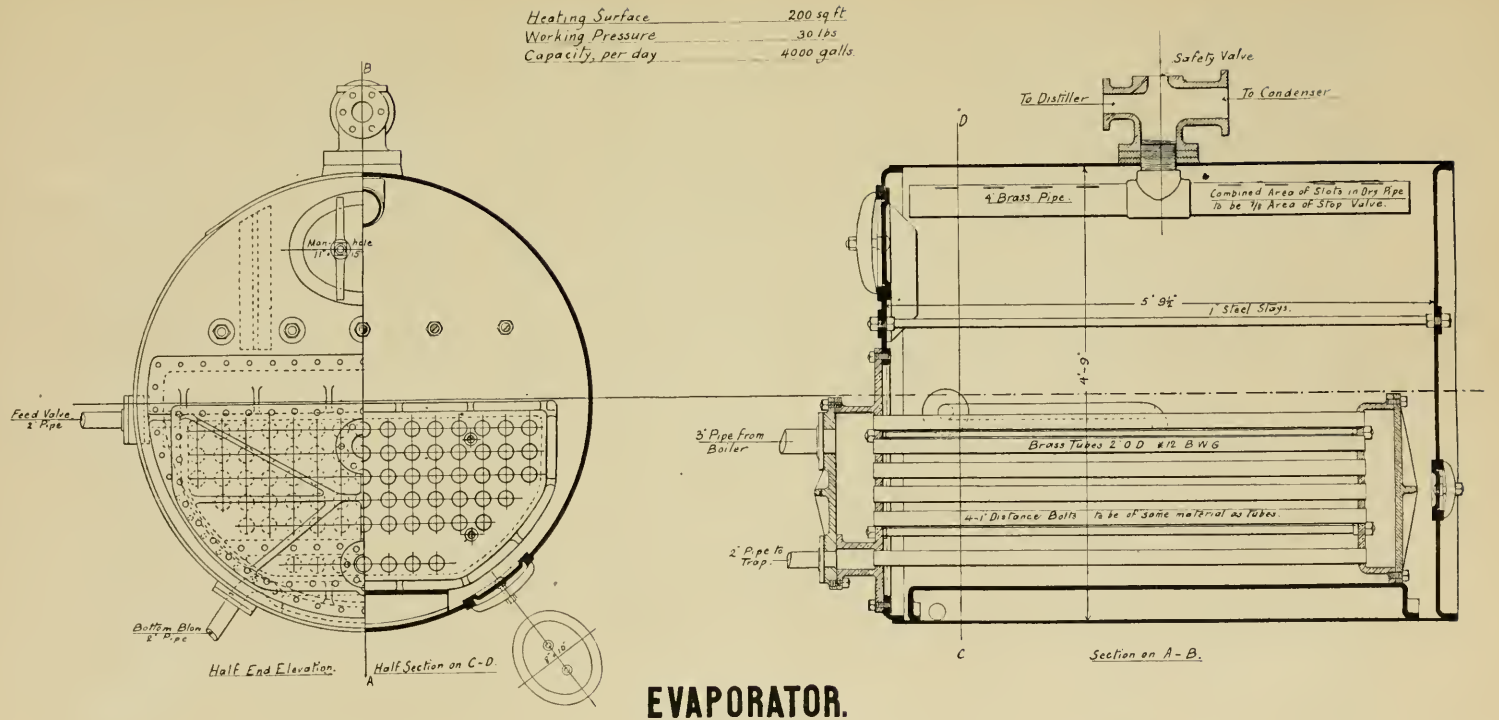
There are brass nipples brazed into the elbows at the ends of each coil which pass through the tube plates and are secured by nuts. The joints between the salt and fresh water sides of the tube plates being made tight by the nuts being recessed at the bottom and screwed down on wicking.

Fig. 41 shows the type of evaporator fitted on most of our naval vessels. It has a cylindrical shell similar to a boiler shell. The arrangement of tubes and steam and water connections are clearly shown.

Steam gauges, water glasses, bottom blow, safety valve, and other fittings, as used on a boiler, are fitted; the evaporator being in reality a boiler whose evaporating agent is steam instead of fire.

This type of evaporator is made in various sizes to suit different vessels, the larger vessels being usually supplied with two, each having about 5000 gallons capacity per day.

Owing to its high evaporative power, an evaporator will prime unless very carefully handled. The presence of a small quantity of salt will make the water bad for drinking purposes, so it is necessary to avoid this. Care must be taken not to carry the water level too high, the best results being obtained when it is just below the upper row of tubes. If carried lower there will be



EVAPORATOR.

Fig. 41.

no injurious results and the uncovered tubes will tend to superheat the steam and reduce priming. From twelve to fifteen pounds pressure is usually carried on the shell when making water for drinking purposes. The stop valve on nozzle to distiller is regulated to obtain the maximum output without priming, and the stop valve admitting boiler steam to the tubes is regulated to keep up the pressure in the tubes to about thirty-five pounds.

When the distillers are on a level considerably above the evaporators, and the connecting pipe has no downward bends the water drains back to the evaporators and the effect of priming is much reduced. On the U. S. S. New York the evaporators and distillers are on the same level. After considerable trouble from priming, the pipe from evaporators was carried well up the hatch; then, with a reverse bend, back to the distillers, the pipe being well covered with non-conducting material. It was then found possible to keep the stop valve wide open without salt water being carried over, and the output was much increased.

When operating in connection with a *condenser*, for making water for the boilers, the evaporator is under a partial vacuum and the product is much larger than when using with a *distiller*. The water produced may be slightly brackish, but the lime salts, which make boiler scale, are left behind in the evaporator, and the common salt (sodium chloride) which is carried over has no injurious effect on the boilers.

A salinometer pot is fitted to the evaporator for taking the saturation. The evaporator should not be blown down until the saturation is 4-32nds.

To scale the evaporator tubes, which should be done when a scale of $\frac{1}{8}''$ or more in thickness has formed, the pipes in front are cleared away, the joint on evaporator head is broken, and the nest of tubes taken out. They are then thoroughly scaled and cleaned before replacing. Sometimes, a spare nest of tubes is carried, which can be put in when the evaporator is opened, and but little time is then lost; the nest taken out being scaled at leisure.

MULTIPLE EFFECT EVAPORATING PLANTS.

Art. 32.—Large evaporating plants are fitted with only the first evaporator, in a set of three, using steam from the boiler. The

steam produced passes to the tubes of a second evaporator, and the steam produced in the second to the tubes of a third. The third evaporator is connected with a condenser and works under a vacuum.

It is said that an efficient plant of this kind will produce twenty pounds of fresh water per pound of coal, which is about two and a half times the evaporative power of a fairly efficient boiler. The U. S. Ships *Rainbow* and *Iris* have been fitted out as distilling ships. Each has twelve evaporators of large size, arranged to work in either single, double, or triple effect. No figures have been published giving data as to their performance.

MANAGEMENT OF BOILERS AND ENGINES ON BOARD SHIP.

(Chap. XXIX., S. & O.)

Work Preliminary to Starting Fires.

Art. 33.—The normal condition of the ship may be taken as at anchor with steam on one boiler and the auxiliary steam pipe; the other boilers closed and filled completely or else to steaming level with fresh water.

The order to get up steam should be given six or eight hours —according to the size of boilers—before the time set for getting underway unless the boilers are provided with circulating apparatus, in which case half that time will be sufficient. The order should also state the speed required.

Select a number of boilers judged to be sufficient, taking those that have been used least, arranging, if possible, to have all in the same fireroom and as far as possible from any boiler that may be out of repair or that may require cleaning while underway—also they should not be far from the coal supply. Remember that the steam pressure will be most easily controlled and economy of coal ensured, if there are enough boilers to furnish steam with moderately heavy fires and moderate draught, and also if the run is to be more than 24 hours long, the fires will have to be cleaned. If the vessel is to manœuvre with a fleet, enough fires should be lighted to furnish steam for a speed two knots greater than that named in the order setting the speed for the fleet. If heavy guns are to be used for target practice it is advisable not to have

any boiler empty for repairs, etc., but fill every one not in use, to check vibrations which would be liable to start leaks.

If the boilers to be used are perfectly full, pump out or drain down the water to middle of gauge glass. See that the cocks on pipes leading to steam gauge and top and bottom of water gauge are open, the air cocks and drain cocks shut. The drain may be open yet choked up sufficiently to allow the boiler to hold water. When a pressure comes on it will blow through and be difficult to close. If the drain cock has a handle take it off to prevent its being accidentally opened. As a check on the water gauge, try the salinometer pot and see if water flows out; also tap on front of boiler with a hammer and judge the height of water by the sound. Start the main boiler stop valve off its seat and open the test cocks. On ships like the Charleston, which have no auxiliary steam pipe system, it will be necessary to keep the boiler stop valves shut until the pressure rises up to that of the auxiliary boiler. In this case the hot air must be allowed to escape by raising the safety valves and keeping them open until steam forms. Otherwise the safety valves should be kept closed. Remove smoke-pipe cover, slack smoke-pipe guys, light gauge and other lamps if there are no electric lights. Close furnace and ash pit doors of all boilers not in use and see their main stop and check valves closed. While this has been going on the coal passers should have gotten out and placed in front of each furnace several buckets of coal containing a good proportion of lumps. If the lumps are larger than a man's fist they should be broken with a coal maul having a rather sharp point so that the lumps will be broken into pieces rather than be pounded to fine dust. If the coal is all dust it should be sprinkled with water to keep it from falling through the bars.

The grate is now to be covered with a layer of coal from three to six inches thick, extending to within about one foot of the door. The thickness will depend upon whether the coal is fine or lumpy. If the layer is too thin air will pass and spoil the draught. If too thick it will take a long time to get thoroughly ignited and then the fires will be too heavy and hard to manage.

Starting Fires.

On some ships it is customary to notify the officer of the deck through the engine-room speaking tube just before starting fires;

on other ships he is notified after all fires are started. All furnaces in one boiler should be started at the same time to avoid unequal expansion of different parts.

If bituminous coal is used the fires may be started by using shovelfuls of live coals from the auxiliary boiler. If anthracite is used it will be necessary to lay a double handful of oily waste or shavings on the front of the grate; cover this with an armful of kindling wood and the wood with lumps of coal.

The amount of wood will depend upon the time available for getting the fires started.

If there is a water circulating apparatus it is started at the same time as the fires and continued until steam has formed. On ships fitted with Weir's Hydrokineter it is usually customary to start them twelve to sixteen hours before lighting fires and have the water heated nearly to boiling point. Instead of keeping fires banked the water may be kept hot in this way with steam from another boiler, and full pressure raised in two or three hours after lighting fires.

While the fires are burning up, the furnace doors are left ajar and ash-pit doors partly closed. As the coal becomes ignited at the front it is worked back from time to time with the hoe and mixed with the coal at the back and fresh fuel is put on in front.

The coal passers now begin to get out rounds of coal at regular intervals until the end of the run.

About this time a deep rumbling sound accompanied by a strong vibration of the boiler is sometimes heard. It is due to strong draught and indicates that there are holes in the fire. If no holes are found, check the draught by partly closing the dampers.

The fact that all the coal on the grate is ignited is known by a bright clear glow throughout the ash-pit. It is now time to close furnace doors entirely and open ash-pit doors wide.

The fires must be kept levelled off, sprinkled with fresh coal from time to time, and kept shoved back from the furnace doors to avoid burning the inner linings. The ash-pits must be kept free from coal that falls through the grates without being burnt, also live coals, both of which are liable to overheat the bars. A thin layer of ashes however may be left to protect the metal. Avoid heaping up fire at the back of the grate, thereby checking the draught.

Since differences in draught, coaling, firing, etc., will cause steam to form at widely different times in different boilers and may cause it to form too soon or too late, the temperature of the water in the boilers should be taken every half hour after fires are started and the fires urged or checked so that the rise of temperature each half hour shall be the same. It should never exceed 36° F. per half hour. If the draught is abnormally poor the blowers may be used, taking care not to exceed ½-inch water pressure. The formation of steam will be shown by escape of vapor from the test cocks, which are then to be shut and all hot air and steam allowed to pass through main steam pipe and into main engines, taking care to open all drains on these pipes, on valve chests, etc. (If as in the case before mentioned there is no auxiliary steam pipe, the safety valves are closed as soon as all air is judged to have escaped and the pressure in each boiler allowed to rise to the maximum, connecting each boiler up in turn to the main steam pipe when its pressure is equal to or a little above that already in the pipe.) As the pressure rises to 8 or 10 pounds it will be necessary to close all drains which are blowing steam, drain steam drums and separator or main steam pipe and open boiler stop valves full (two or three turns if globe valves). The smoke-pipe guys previously slackened must now be set up moderately taut. It will take an hour, more or less, for steam to attain its full height, the time depending upon a great variety of circumstances and conditions. As it rises keep a good lookout about the boiler and pipes for leaks of water and steam. If anything serious develops it will be necessary to start fires in another boiler at once.

Control of Steam.

The management of the steam will require the greatest skill and care as the pressure reaches the limit and the fires have become thoroughly ignited. Opening furnace doors and pumping cool water into the boilers to keep down steam pressure is strictly prohibited. These methods must be resorted to only when everything else fails. It is also inadvisable to open connection doors. The first thing to do is to shut dampers and partly close ash-pit doors. If these do not answer, open the bleeders. On all modern war vessels the bleeders are purposely made large enough to give good control of the steam. Care

should be taken however not to open the bleeders suddenly, as by doing so there is danger of cracking the condenser tubes. If the bleeder is not sufficient, raise the safety valves. On our most recent naval vessels the safety valves are connected with the dry pipes so that there is not the danger of lifting water out of the boilers which used to cause such dread of raising safety valves. A good practical and economical expedient for controlling the steam is to see that the evaporator is not in use while steam is forming. Then start it and stop it as occasion requires to use surplus. All the ventilating blowers may be started and stopped for the same purpose if the evaporator is not sufficient, also bilge and fire pumps. A large amount of surplus steam may be worked off to advantage by having the main engines ready to try just about the time steam reaches the limit—but this is not always convenient or practicable. When steam is up to the limit and the fires are burning well, report to engine room, "ready to get underway." Be sure about the fires before making this report. A poor fire will expand a quantity of steam bottled up in the boiler until the pressure rises to the limit. A few strokes of the engine may carry off all this pressure and then the water may go.

Standing By.

After all is ready in the fire room, it often happens that the time for getting underway is postponed. If the delay is to be for only two or three hours, the fires may be left spread and lightly coaled from time to time, keeping the evaporator working to full capacity, the ventilating blowers all going and if found necessary by experience, keep the bleeders partly open. If some such precautions are not taken, at the end of the time set, the efforts to keep steam down will have so deadened the fires that after the main engines have run a short time the steam will fall rapidly, thereby incurring the risk of the ship becoming unmanageable while going out of port or not being able to keep place in line or to execute the necessary manœuvres with the fleet.

Banking Fires.

For a delay of three to six hours, the fires may be banked, first allowing them to burn down a little, cleaning them if necessary, then shoving them towards the back of the grate in a heap. If

banked when too heavy the necessary stirring up may cause the pressure to rise so fast that it will be hard to control without waste. Fires should not be banked at the front of the furnace, as in that case cold air will pass through the grates at the back and strike the back tube sheets, the most sensitive part of the boiler. When fires are banked the dampers should be closed and ash-pit doors partly so, otherwise a large amount of coal may be wasted heating up the air which sweeps over the fires. If dampers are too tight and the coal contains much gaseous matter, explosive gases may form and explode in the combustion chambers. If ash-pit doors are shut too tight there is danger of overheating and melting the grate bars. Lying under banked fires is liable to cause leaks about the boiler seams and tubes. There is a variety of opinion with regard to the exact causes but no question about the fact. If the delay is to exceed five or six hours it is better not to bank fires but to let them burn down slowly and when they have completely died out, haul them quickly and immediately, close the furnace and ash-pit doors and dampers. A long series of experiments tried on German naval vessels shows that to lie under banked fires for twenty-four hours requires as much coal as would be necessary to start all the fires afresh. The exact amount should be learned by experiment for each vessel and a record kept for reference.

On naval vessels, however, it is sometimes necessary for military purposes to lie under banked fires in order to be ready to get underway at short notice at some unknown future time, and considerations of economy of coal and injury to boilers must be disregarded. When fires have been banked for about 12 hours a systematic cleaning of them must be begun, taking one-third the whole number each watch.

When under banked fires and the order is received to get underway, if there is plenty of coal on the floor plates, it will take about ten or fifteen minutes to get all the fires spread and fifteen to thirty minutes more, under ordinary conditions, for the fires to burn up before it will be safe to attempt to get up anchor.

Management of Fires Underway.

The aim is to keep a uniform pressure of steam regardless of the varying speed of the engine and at the same time to economize coal. As the boilers are in separate compartments and

often the main engines can neither be seen nor heard it is advisable to provide some speed indicator or simple apparatus by means of which the water tender will be kept informed of every change and that he may know at once if fluctuations of steam are due to variations of speed. He should also be informed in advance, when possible, of proposed changes.

Firing a Furnace.

A furnace should be fired when the layer of coal has burned down to three-fourths its normal thickness. First close the damper, level the fire, throw a few shovelfuls of coal on the front of the grate to check radiation, then begin at the back spreading the coal evenly all over and work towards the front. Push the coal away from the furnace door, work quickly and get the doors shut as quickly as possible, then open the damper. Then clear the spaces between the bars with the "pricker bar," and haul the ash-pans. Any good live coals that may have fallen through the bars may now be separated from the ashes and returned to the furnace. The fires should be carried about 5 inches thick for anthracite coal and moderate draught, increasing the thickness for stronger draught and bituminous coal to 10 or 12 inches.

The furnaces must be fired in rotation, each succeeding furnace being chosen as far as possible from the preceding one. If a fire is in good condition, as soon as the fresh coal has ignited a bright clear light will be seen in the ash-pit. If after this the ash-pit looks dull, the spaces between the grate bars must be thoroughly cleaned with a pricker bark. If this cannot be done owing to slag sticking to bars, use a slice bar to detach it and rake to haul it out.

Cleaning Fires.

If there is much slag or clinker on the bars it will be necessary to give the fires a thorough cleaning. As a rule fires will do without cleaning for about twenty-four hours, so that on runs not exceeding a day no thorough cleaning will be required. If there is any chance of the run being longer, the cleaning should begin about 12 hours after the fires are started, one-third of the fires being taken each watch.

The front connection doors are chalked 1, 2 and 3, to show which furnaces are to be cleaned by the respective watches. The

fires to be cleaned by any one watch should be selected as far apart as possible. Before beginning report the necessity to the engine room. First allow the fire to burn down as thin as possible without allowing air to get through, taking care to keep it levelled off and allowing no holes. An expert water tender will also, at the same time, gradually increase the water level in the boiler so that while cleaning fires and afterwards while fires are burning up, he may shut off the feed as well as the blow entirely and thus secure a more uniform development of steam.

In the meantime get the necessary tools ready, the ash hose led out, and remove all coal from before the furnaces. Begin by closing the damper, then with the hoe shove back all the good fire, leaving the slag and clinker exposed; dislodge the latter with slice bar, and remove it with the rake, whereupon it is immediately wet down by a coal passer. Now haul the good fire forward leaving the slag and clinker at the back bare. Remove it as before. Finally spread the good fire evenly over the whole surface of the grate. If the amount left is not sufficient a few shovelfuls may be taken from the furnace of another boiler. Then sprinkle the whole with fresh coal, open the damper, and haul ash-pans.

Instead of shoving the good fire back it may be pushed first to one side then to the other. When wetting down ashes be careful to not get any water on the front of boiler or furnaces. The operation should be completed in from 8 to 10 minutes according to the amount of clinker and to the way in which it sticks to the bars. When working full speed with forced draught the operation of cleaning fires often consists in hauling out of the furnace everything good or bad and starting a new fire. It takes about four minutes.

After cleaning a fire time should be given for it to get into good condition before beginning to clean another fire.

Sweeping Tubes.

After steaming several days with bituminous coal and indifferent draught, the tubes will begin to choke up; this will be indicated by a fall in the steam pressure if the draught is poor, but if the draught is good, ashes and cinders will be thrown out of the smoke-pipe. The exact condition of affairs is ascertained by opening the connection doors. If the tubes require cleaning

it may best be done by using a steam jet and flexible hose often provided for the purpose, first closing ash-pit doors to check the draught. Before beginning allow the fires to burn down somewhat and ascertain if there are any wash clothes or clean hammocks on the line. If so inform the officer of the deck through the engine room of the necessity of sweeping the tubes, in order that he may have the wash-clothes, etc., piped down. Sweeping with steel or coir brushes is more tedious. In any case do not take time to clear tubes that may be choked with salt so that the brushes do not easily pass through. Begin with the top row of tubes and when finished sweep out the front connections before closing the doors.

As sweeping the tubes checks the formation of steam only one nest should be swept at a time and while this is going on fires must be urged in the other boilers. The feed may also be shut down for a time.

Routine of the Watch at Sea.

The routine is about as follows: begin cleaning fires about 15 or 20 minutes after the watch comes on and continue at intervals until all the fires assigned to the watch are cleaned, which will be about six bells. After each fire is cleaned it must be allowed to burn up and get into condition for making steam. After this it is useless to wait any longer before beginning to clean the next fire. Naturally the intervals of time between cleaning of different fires will vary according to the amount of fresh coal required to get the fire up to its original thickness. As soon as the fires are all cleaned, the ashes wet down and heaped near the ash-hoist, report to the officer of the deck through the engine room that ashes are ready for hoisting. Several deck hands will then be detailed to carry the buckets from the ash-hoist on deck to the ship's side and dump them. A fireman is in the meantime detailed to get the ash engine ready and the coal passers stand by to fill ash buckets. The fire room is to be swept clean as the last buckets go up and a round of coal for the next watch is laid out in front of all furnaces except the one that is to be cleaned first by the next watch. That fire is to be allowed to burn down and the water level in the boiler is gradually raised a little above the normal height. During the whole watch a steady feed, both with regard to quantity and temperature, is to be kept on all boilers

except in cases mentioned, where for special reasons the water level is raised or lowered. The fact of the check valves working is ascertained by putting the ear to the valve chamber. The feed pipe inside of check away from the boiler should not be hotter than the feed water. If the amount of water in the gauge is greater than it should be judging from the normal feed and known opening of the check, the cause should be inquired into at once. When the boilers are placed in an athwartship direction and the ship has a list to port, the water must be carried low in the front gauges of port boilers and high in front gauges of starboard boilers, and vice versa. If oil appears in the gauges it is an indication that the surface blow must be used. If for any reason salt water is used in the boilers, the saturation must be taken once a watch (or oftener) and the density not allowed to exceed $\frac{4}{32}$. When blowing simply to reduce the saturation, the bottom blow is always used, as the coldest water is then blown out. Having shut off the feed open the blow very gradually and allow the water level to sink near the bottom of the glass. If the weather is rough or the ship has a list it may be necessary to pump up the boiler above the natural level and only blow down to that level. The water gauges must be blown through occaisonally to clear them out, and the test cocks used frequently as a check on them. If there is much difference in the pressure indicated by steam gauges of different boilers the cause must be discovered. It sometimes happens that stop valves become partly closed by accident.

The thickness of the fires must be kept proportioned to the strength of draught. Increase of draught has a tendency to raise the water level and a decrease to lower it; therefore when working under strong forced draught when it is desired to reduce speed, half an hour's notice should be given, the draught gradually reduced during that time and more water pumped in. If necessary to stop the engines suddenly, get rid of surplus steam with bleeders or safety valves, or both. On the other hand half an hour's notice should be given before putting the blowers on full. In the meantime fires must be built up thick and water level reduced, otherwise air will be blown through the grates and water may be lifted so high as to go over into the engine. Coal must be used alternately from top and bottom bunkers in order that the metacentric height of vessel may not be altered. It

must also be used equally from both sides of vessel and taken as it comes, not picked over.

Water in boilers must be tested for acidity with blue litmus paper every 24 hours. If found acid put a few pounds of carbonate of soda into feed tank from time to time until the acidity is corrected.

The double bottoms in fire room must be sounded, temperature of fire-rooms and bunkers taken every watch, the regulations with regard to use of lamps in bunkers enforced, a close watch must be kept on water in bilge and the strainers must be kept clear. At sea make a practice of keeping all W. T. doors in bunkers closed, as far as practicable.

Starting an Additional Boiler.

Proceed as before described for getting up steam, except in this case the main safety valve must be raised to allow escape of hot air, and must be lowered again when steam forms. The boiler stop-valve cannot be eased off its seat, so if it is a globe valve it will probably stick fast when hot. When it is desired to open this valve, slack back the nuts on the yoke about half a turn, open the valve a very little, then screw up the nuts. Great care must be taken not to connect up this boiler until the fires have thoroughly burned up and are in condition to make steam and the pressure is equal to or greater than that on the other boilers. Drain the branch pipe between the boiler and stop valve, also stop valve chamber. Do not open the valve wide at first but unseat it until steam is heard to pass through, then leave it alone for a few minutes before opening to normal width. While this is going on watch the index of the gauge closely to observe if there are any violent fluctuations. Also watch the water gauge to see if there is any tendency to lift water. If there is, shut off the stop valve partly or wholly until these fluctuations cease. Neglect of the foregoing precaution is liable to be attended with loss of life.

To Disconnect a Boiler.

Allow the fires to burn down as if for cleaning, keeping them levelled off. When it is judged that they will make no more steam, close the stop-valve, partly close ash-pit doors, and shut

off feed and blow. When fires have almost burned out close ash-pit doors completely. If steam should rise above the limit the boiler stop-valve may be opened for a minute, then closed. If there is any evidence of the presence of oil in the boiler the surface blow should be used to get rid of it so that when the boiler is finally emptied a layer of oil will not be deposited on the interior. When fires are out the furnaces must be hauled and may then be primed if there is any chance of the boiler being wanted again. Before priming be sure that the grate bars are not hot enough to set the coal on fire.

Preparations for Coming into Port.

Upon receiving notice that the ship will come to anchor at a given time regulate the firing so that the fires may burn down as much as possible, having due regard to the necessity of keeping steam to manœuvre the ship. Make an exact estimate of the amount of coal on hand, allowing for what will be required to reach port. If there is no auxiliary boiler select some one main boiler to be used in port, choosing one that has been used least, provided it does not require repairs and is not adjacent to one which must be entered, and provided also that steam connections are such that it may be kept connected with the auxiliary steam pipe service, while making repairs to leaky joints and sections of pipe or overhauling boiler stop-valves that may require such attention. Make an inspection to see if the list of repairs reported to be necessary is correct and complete. Look at the escape pipes to see if any of the main safety valves are leaking, also inspect steam whistle and siren. If there is more coal out than is necessary return it to the bunker or heap it in front of the boiler which is to be used in port. Shut any additional water-tight doors in bunkers that may be found unnecessarily open. Send up all ashes without regard to the hour. If there is an auxiliary boiler to be used instead of a main boiler, start fires in it in time to allow steam to form and rise slowly to the required pressure by the time that steam on the main boilers is used up, which will be about an hour or two after arriving in port. Have coal ready to send up for use in the steam launch.

Arrival in Port.

Upon receiving word that the engines will no longer be required the fires are allowed to die out in all except the boiler to

be used for auxiliary purposes; the ash-pit doors partly closed and dampers wholly shut. When after about 12 hours time the fires are out they may be quickly hauled and the furnace and ash-pit doors again shut. The time required for the boilers to cool will vary with the size and other conditions, being about 36 to 48 hours for single-ended Scotch boilers 12×12 feet. If possible, work on the boilers should be postponed until they have cooled off. If for any reason it becomes necessary to blow down a boiler at once, shut it off from the others, raise the safety valves until the steam pressure has fallen to about 25 or 30 pounds in excess of pressure of water overboard at the level of the bottom blow. Blowing then will cause less jar and shock to boilers and pipes.

While waiting for the boilers to cool the fire tools may be repaired, slice bars straightened, new heads put on hoes, shovels trimmed and coal bunkers repaired. Work (hereafter to be described) on bunkers, etc., may be done.

If there is no work to be done on a boiler which necessitates pumping out, if the water is fresh and not very greasy, it should be left in.

Cleaning Boilers Outside.

When the boiler is cool, sweep tubes, remove grate bars and clear them of slag and clinkers. Clear out combustion chambers, furnaces, and ash-pits. Inspect the tube sheets and make a record of the number and position of all leaky tubes, seams, rivets, etc. Then scale the tube sheets, plates in vicinity of leaky seams and rivets in order that the tubes may be expanded and leaks caulked. Examine all stay rods (if any) through tubes and try nuts with wrench to see if they are too tight or too loose. Also clean plates on outside of boilers in vicinity of leaky seams and rivets. If work requires it, now pump out the boilers and proceed to expand tubes, cut out leaky ones as required, caulk rivets, seams, etc. Salt in the tubes may be softened by turning in a jet of steam for several hours. Salt in ash-pits is softened by building a dam of ashes and filling pit with fresh water allowing it to stand overnight.

Scaling Boilers.

Do not open boilers until ready to scale them, as contact with the air hardens the scale and makes it stick. When ready open

the drain cocks. Remove all man and hand-hole plates, and lower a lamp into the boiler to see if the air is respirable. If not, wait until the foul air escapes. Stop with wooden plugs all openings of pipes in lower part of boiler in order that they may not become choked with scale. Then proceed with scaling as quickly as possible, taking care not to remove scale from any but heating surfaces. The back tube sheets, crown sheets, and the junction of the two require the greatest attention.

After scaling and before washing out is the time to do any work that may be necessary inside. Inspect the zinc plates and renew them if they are one-half used up. These plates should be supplied at the rate of one for every 30 I. H. P., the size being 12″ × 6″ × 1″. If the metallic connections with braces or boiler have rusted file off the rust. Examine all internal pipes and their supports. When scaling and other work is completed, haul out the refuse from the bottom of boilers with light hoes provided for the purpose, then wash out the interior with steam fire hose. Finally remove wooden plugs which were put in the pipes and replace all plates, using same gaskets if good and putting on fresh black lead or chalk on one side and paint on the other if required. If gasket is not good, scrape bearing surface on plate clean, paint it with red lead and lay the rubber gasket in place. Then cover other surfaces of gasket with black lead or chalk. If the plate does not fit well, Tuck's packing makes a good gasket, thinning down and lapping the ends and wedging it in the angle between the flat bearing surface and the ridge on the inner side of plate. Asbestos cardboard ⅛″ thick soaked in boiled linseed oil is excellent, taking care to black-lead the surface which bears against the boiler. Sometimes, especially with auxiliary boilers and those of the locomotive marine type, all parts of the interior are not accessible for cleaning and scaling, and cannot be reached even with a stream from a hose. In such cases the cleaning is completed by boiling out with solutions of soda and milk of lime. Pump up the water to the top of the glass, then introduce through a cock provided for the purpose, or else through a man-hole plate, a couple of pounds of soda and an equal quantity of lime dissolved in water. Then get up a pressure of steam to 30 or 45 pounds and boil four to six hours. An emulsion will be formed and will float on the surface and must be blown off through the surface blow. After this the

boiler must be cooled, emptied, and the bottom cleared of the deposit which will be found there. In case of coil boilers, especially the small ones used in launches, a pint of kerosene introduced in the feed water from time to time while the boiler is under steam, is most efficient in softening deposits, especially oily ones.

Now take up the boiler fittings, grinding in the cocks and valves, packing valve-stem stuffing boxes, etc., and examine main safety valve, unless it has been done within the past six months.

Filling Boilers.

When all repairs inside and out are completed and grate bars cleaned and replaced, take advantage of the first opportunity to fill the boilers with fresh water, either from shore or from the evaporator. The former is much cheaper and the latter rather better for the boilers.

The regulation with regard to using the boilers to trim ship has sometimes been disregarded on account of the difficulty in keeping a modern ship on an even keel without using them.

Light wind abeam when swinging to tide, lowering one boat more on one side than the other, mustering the crew on port side of quarter deck, water in double bottoms, emptying a boiler on one side or the other for repairs, pumping fresh water out of a boiler for use in the auxiliary, are among the most frequent causes of a ship's list. If the coal used for auxiliary purposes is taken alternately from starboard and port bunkers every twelve hours, there need never be any trouble from this cause.

In former times the guns were run in and out or the heavy forward pivot gun shifted to keep the ship upright, but with the modern guns as placed this cannot be well done. If the regulation is to be enforced, the boilers should be filled to the top for better preservation. Otherwise it is better to fill them to steaming level to allow a margin to vary the level up or down to trim ship. Boilers are generally filled by using a feed pump, the fresh water being run into the feed tank from a hose connected with a pump on a water lighter or hydrant on the dock. In filling a boiler with fresh water, bicarbonate of soda should be put in as the water is entering the boiler—about a pound of soda (dissolved in water) for each ton of water in the boiler.

If the upper man-hole plates are off it is sometimes simpler to

turn the hose in direct. If for any reason salt water is to be used it is run in through the bottom blow, first opening the air cock, or lifting the safety valve to let out the air. Avoid filling the boilers in this manner at ebb tide in a river or when the water in a harbor is dirty. After the boilers are filled, *never before*, furnaces may be primed, but this is better postponed until about to get up steam, as it checks circulation of air through furnaces, thus leading to deposits of moisture and rust. The dampers should be kept open and ash-pit doors off. Smoke pipe cover must be kept off in fine weather, and must be put on and the fire-room hatches covered before rain. Paint on front connection doors, uptakes, boiler shell where accessible, smoke pipe, etc., must be renewed from time to time, using red lead or brown zinc as a priming coat. See that decks over boilers do not leak and that the bilges underneath are kept dry. In damp weather drying stoves are kept burning in fire-rooms where there is no steam, changing them from boiler to boiler. The same in freezing weather if the temperature falls near freezing point.

Coal Bunkers.

When work on boilers is completed, the next thing in order is to inspect the coal bunkers. Before entering a large, badly ventilated bunker, the air should be tested by introducing a safety lamp. A blue flame on the outside of the wire gauze, or the lamp becoming extinguished, indicates the presence of an explosive gas and the bunker requires further ventilation. Care must be taken that the door of the lamp shuts tight and that there is no accumulation of soot on the inside, otherwise it will fail to act and cause an explosion.

The fittings of water-tight doors are to be overhauled, coaling ports and bunker deck plates made tight, valves and pipes for extinguishing fire put in order, and broken braces renewed. Scale and paint inside and out where required, put electric lights and fire alarm apparatus in order and clear bunker drains. The outer wall of lower bunkers being part of the skin of the ship and in contact with water outside, is cold and condenses moisture to such an extent that it is seldom dry enough to paint unless the temperature of the external air being less than that of the water, allows the air in the bunker to be sufficiently cooled or the ship

is in dry dock, in which latter case, the bunker is often inaccessible from being partly filled with coal. Even if painted the paint is soon knocked off by coal striking the inclined surfaces when thrown down from the upper bunkers. Probably the best thing to do is to wipe over the surfaces occasionally with waste dipped in mineral oil. When the work and painting are done, get the bunkers ready for coaling by restowing coal where necessary in such a manner as to facilitate receiving an additional quantity. Bunkers must always be kept well aired by using the gratings instead of deck plates as much as possible, being careful to put on the plates every morning before the decks are washed. Also keep as many of the water-tight doors open as possible during the day and shut them at night.

Fire Room.

While at work on bunkers, the pumps in the fire room, sluice valves, strainers, and valves for pumping out the compartments, may be put in order.

Double Bottoms.

The last work will be cleaning and drying out the double bottoms, and renewing the cement and paint as required. Before entering a compartment let down an open light. If it does not burn brightly, the compartment must be ventilated; this is easily done after the man-hole plate is removed, by starting the compartment pump as if to pump out water. If as sometimes happens there are no pipes for pumping out the compartments, a small blower should be procured and provided with a flexible hose to discharge air into the compartments.

In the English navy most elaborate precautions are taken to prevent men employed in painting confined spaces, such as double bottoms, from suffering from lead poisoning. No such precautions are taken in our navy, nor do they appear necessary. However it is well to furnish the surgeon with a list of the men employed in order that he may keep a lookout for any symptoms and use necessary preventative measures in good time.

While laying on the cold iron the men should have a piece of rubber or canvas under them to prevent getting rheumatism.

Finally clean fire-room bilges, clear strainers, etc.

MANAGEMENT AND CARE OF THE MAIN ENGINES AND AUXILIARIES.

(Chap. XXX., S. & O.)

Preparing to get Underway.

Art. 34.—When preparing to get underway, delays may be occasioned by a gasket blowing out, a valve coming off its stem, a lever or screw sticking, cylinder relief valve spring breaking, stuffing boxes leaking, etc. For this reason it is a good plan to arrange to have all the necessary auxiliary engines ready, and to turn the main engines about an hour before the time appointed to get underway. On medium and large ships this will make it necessary to begin preparations about two hours before the *time set for getting underway*. Generally the first thing to do is to get the capstan ready and turn steam on, as that engine *may* be wanted to " heave short " or " unmoor," some time before getting up anchor. It is to be understood that all steam engines of whatever size are to be oiled and drained before they are started. The greater the emergency, the more important it is to take these precautions, otherwise the engine is *liable* to be disabled just when most required for use. The work of getting ready is divided between the machinists and oilers, each of the latter reporting to the machinist in charge when all is ready on his station. If there are not enough men on the watch, part of the relief is called and kept until fairly underway. *A man should be stationed at the* speaking tube during the whole time. If water is liable to be used on the crank pins, it is a good plan to cover all iron bright work in their vicinity with a coat of white lead and tallow. A coat of tallow is sometimes put on inaccessible parts in order that the melting of the tallow may afford a means of judging if the part is getting warm.

Open the outboard delivery and injection and start the circulating pump; then start the air pump. Turn steam on the cylinder jackets, if any, and drain them, start the engine stop-valves off their seats, allowing the hot air and steam, which at this time should have begun to form in the boilers, to pass through the cylinders and into the condenser. Besides warming the cylinders the steam will serve to form a vacuum in the condenser. See that the drains of the cylinders and steam chests are open. They

should be shut when steam, instead of water, begins to come out. If the engines are 3000 I. H. P. or larger, *an hour* may, with advantage, be employed in warming them up gradually. See that nothing is stored about the working parts of the engine and that there is nothing loose about the engine room likely to get into contact with the working parts when the ship rolls; see that all set bolts and split pins on the moving parts are all in place. Remove the gaskets from the ends of the journals and see that the turning engine is disconnected. Fill the oil cups and cans and see that the wicks are in order, and that the oil pipes are clear. It is well to put in the wicks long enough before the engine is turned, to allow oil to trickle down naturally and flow over the journals. If in a hurry pour some oil down the pipes from a squirt can or feeder. As the oilers make the rounds they should keep a lookout for loose bolts, nuts, keys, set screws, oil cups, etc. Also *slacken* the nuts of the stern stuffing box gland. If there is a clutch coupling, see that it is coupled up properly; neither too tight or too loose; that the brake is *slackened* and secured and all loose articles in the shaft alley stored for sea. Try all valves on the water service to see if water will flow through, then shut the main supply valve and leave the one generally required open, so that when the engine is started water may be turned on by simply opening one valve.

Examine bilge pump and bilge injection strainers; warm up and try the reversing engine.

Turn steam on steering engine and try it; also try the steam whistle, syren, engine room telegraph and gongs. The last generally has several bell pulls placed in different parts of the ship. *Try them all.* On some ships the whistles and bells are tried by the officer-of-the-deck. There should be a distinct understanding beforehand as to whose duty this is: *better a written memorandum.*

In case of an engine with two cranks and a variable cut-off, it is generally necessary to run the cut-off out about full stroke, in order that the engine may be started promptly. In case of compound or triple expansion engines, it is well to be ready to let a little live steam into the receiver, *the amount being found by experiment.*

When all the foregoing preparations have been made and inspected by the engineer on duty and the steam pressure in the

boilers is high enough, get permission from the officer-of-the deck to turn the engines and pass the word around the engine-room to "stand clear." When the engines are being tried a look-out should be kept on deck, since the effect upon the ship of the motion of the screw cannot be observed from below, and it varies considerably with wind and tide. When possible, the engines should make a number of turns each way to work the water out of the cylinders. If no special lookout is kept on deck, never make more than two or three turns in one direction before reversing the engine. In any case the engine should be worked slowly. If all is found to work well and the vacuum in the condenser is as high as usual, shut the main engine *throttle valve* and put the links in mid-position.

Now make an inspection of the engine and fire-rooms, see that all men are at their stations; that none have neglected their duties; that there are no signs of leaks starting in boilers or pipes; and that the auxiliaries are all working in a normal manner.

When the time set for getting underway arrives, report to the chief engineer, who reports to the commanding officer, that the engines are ready. Then get a pump ready to start promptly on the fire-main as the hose will be used to wash off the anchor and chain.

If, after all is ready, the time for getting underway is postponed several hours, the wicks should be taken out, steam shut off the capstan and steering engines; air and circulating pumps slowed down. If the fires are under complete control and there is no chance that the bleeders will be required, these pumps may be stopped and the outboard valves closed.

Underway.

Upon receipt of orders to stand by to get underway, a machinist should stand by the reversing gear and an oiler or other reliable man at the engine room telegraph and voice tube and, if necessary, another at the throttle. Start the engines slowly and allow about *five* minutes for gradually opening out to full speed. After this a machinist must always be stationed at the reversing gear until arrival in port and at anchor, unless relieved by some competent and authorized man who has had experience in handling the engines. When underway, keep a close watch on all parts of the engines that have been adjusted since the last run, until sure that these parts will not heat.

After the engines are fairly underway and the ship well clear of the land, the cut-offs, if previously run out to facilitate handling the engines, are now adjusted to insure greater economy of steam consistent with smooth working of the engines.

For economy, the terminal pressure in the L. P. cylinder should be equal to the back pressure plus the pressure required to overcome the friction, or, roughly speaking, it should be a few pounds above the back pressure.

Economy is perceptibly increased by linking up, thus increasing the compression and partly filling the clearance spaces. As this shortens the travel of the valve, it will ultimately (after a number of years) wear a ridge on the valve seat which will have to be scraped down. As it also reduces the port opening, it must not be done in those few rare cases where naval vessels are worked at full power.

Theory and experiment both show that, with compound or triple expansion engines, it is much more economical to work with full boiler pressure and cut-off short, than to carry a reduced boiler pressure and throttle down with cut-offs run out.

Smoothness of working is generally to be obtained by linking up. As naval engines often work at about one-fifth power, the pressure in the L. P. cyl. is so small that linking up has no effect. In such cases the engines will work more smoothly if run at a higher speed, or, if this cannot be done, by carrying less vacuum and higher temperature in the hot well. After all adjustments have been made, indicator cards should be taken to make sure that all is going on in the cylinders as intended.

A general inspection should now be made throughout the department, taking particular care to see that the bilge pump is working and its strainer is clear. The order "full speed" is to be understood as the greatest speed that can be made with the boilers and fires in use at the time.

The order to change from full speed in one direction to full speed in the other, should never be given except in great emergencies. The engines should be slowed down and stopped before reversing. But if the order to change from full speed in one direction to full speed in the other should be given, it must be executed promptly at the risk of *breaking the shaft.*

After the engines are started, it is a matter of pride to keep them going to the end of the voyage. This requires close watch to

anticipate and prevent any accidents. Also some ingenuity in repairing and correcting defects as they appear. If it should become necessary to slow down or stop, always give the officer-of-the-deck as long notice as possible in order that he may inform the commanding officer, and the latter decide what to do. All reports of this kind should be accompanied with a statement of the nature of the difficulty, the probable length of time before the engines will be ready to go ahead again at their former speed, and any other information that will be of service to the commanding officer in aiding him to come to a decision with regard to what he is to do with the ship. The chief engineer must be notified at the same time. In case it should be necessary to stop the engine before the officer-of-the-deck can be notified, he must be informed as soon as possible afterwards. Use the *engine room telegraph*, voice tube, messenger, in the order named. While the engines are running, everyone in the engine room must keep a watch on all gauges, thermometers, counters, stuffing boxes, bearings, etc., and listen to the combination of sounds made by the various working parts and called by the French "le chant de la machine." Any changes in the indications of the gauges, or variation of any of the normal sounds, must be investigated and the causes ascertained. When a gauge gives a peculiar indication, first see whether it is shut off or out of repair. Turn the cock on full, then shut it off and wait until the index falls to zero. Test a thermometer by using another in the same place. If a stuffing box leaks, take notice if the leak is all on one side; if so the rod may be out of line, and the stuffing box gland should not be set up tight. If there is a slight dew on large brasses, they cannot be hot. If there is a lather formed at the ends of the journals they are properly lubricated and cool. If there is no lather, but the oil running out is discolored by the abrasion of metal, the lubrication is insufficient. If the oil runs out clear and unchanged in appearance, the supply is too great.

A great deal of information with regard to the running of an engine may be obtained by the sense of hearing. First the sounds may be divided into two general classes, the normal and the abnormal. Among the former may be mentioned a leading thump of one of the crank pin brasses as the pin passes one dead point. It rarely happens that all the crank pin brasses are so evenly adjusted that some journal does not make more noise than an-

other. Then there is the slip of the link block in the link, the steam flowing into the valve chest, exhaust into the condenser, the valves of the different pumps, periodic blowing of the traps, etc. The abnormal sounds will be treated of later.

The two foregoing general classes may be divided into sounds which are coincident with the motion of the main engines and which therefore must come from some part connected with them, and on the other hand—sounds not coincident. These two latter classes may be further divided into the light tinkling sounds which must obviously be made by looseness of some light piece, and the dull heavy thuds which come from heavier parts. A good ear can also distinguish between the clear bell-like sound given out by solid brass and the less musical note made by an iron piece of same weight. By keeping in mind the above classification many normal and abnormal sounds may be quickly traced to their origin. There are some sounds so common with certain engines that they may as well be mentioned here, although, strictly speaking, they should be treated of with other abnormal noises.

First is water in the cylinders, which causes a thump on one or both ends, and may often be detected by observing water gushing out around the indicator pipes and cocks and piston rod stuffing box. If suspected, the cylinder relief valves or drain cocks on the corresponding ends of the cylinders must be opened. If as often happens, there is no pressure in the cylinders the cut-off may be run in until the pressure in the receiver rises above the atmospheric pressure, unless the cylinder drain connects with the condenser.

There is another sound, a harsh rasping one, often heard in a L. P. cylinder when the engines are slowed down preparatory to entering port. It is caused by a small amount of water in the cylinder and will cease when the engine is speeded up again. If that noise should occur when the engines are first underway, it might properly be attributed to the piston springs being too tight. If caused by a small amount of water, it does no harm, though unpleasant to listen to.

To discover in which crank pin or main journal there is a thump, accompanied by a jar of the engine, take notice which crank passes the dead point when the sound is heard. An additional check is to flood the journals in succession with oil or water

through the oil pipes, and observe if the sound is deadened. First try the crank pins, then the crosshead journals, then the main shaft journals. If the sound continues, it may be that the oil or water did not get access to the bearing, or else the noise may be due to the piston being loose on the rod, or the follower loose on the piston. Thumps due to loose crank pin or cross-head brasses, loose piston, or loose follower, will be greatly reduced if nearly all the load is taken off that cylinder by readjustment of the various cut-offs. It may also often be reduced by linking up. If it is due to a loose core plug, follower bolt or anything solid inside being struck by the piston, the foregoing measure will have no effect in diminishing the noise and the engine must be stopped as soon as possible. When the piston springs are not tight enough, they alternately contract and expand towards the end of the stroke, causing a knocking of the rings against the walls of the cylinder, giving out a clear metallic clacking, without producing any vibrations in the engine such as would have been observed if the journal brasses, piston, or follower were loose. The only damage will be leakage of steam and the remedy may be postponed until the arrival in port. Metallic packing sometimes gets loose and causes a clacking sound at the end of one or both strokes, which may easily be mistaken for something inside the cylinder, especially if, at the same time, the loose packing causes a poor vacuum, which latter gives rise to a coincident jar of the whole engine from the consequent change of distribution of the pressures on the piston. A sudden stillness pervading the engine room is one of the most alarming indications, for it is a sign that some large journal is getting hot. If accompanied by an odor of burning oil the indication is confirmed. If a thump is heard about the cylinder when the piston is near the middle of the stroke, it must obviously come from the slide valve, and is probably due to the valve being loose on the stem or else striking something at the end of its stroke. If the latter is the case, the noise will be stopped by linking up which will reduce the travel and make it possible to continue working the engine, although it is advisable to stop as soon as practicable to remove the obstruction. If due to the cut-off blocks on the back of the main valves striking something, the cut-offs should be run out and the steam regulated by throttling.

A sharp clear-cut sound of exhaust steam in the exhaust pipes

indicates rapid condensation and the amount of the injection may be somewhat reduced. A dull sound in steam or exhaust pipe is an indication that the boilers are foaming or, at least, that the steam is wet. A thump at the end of the stroke of a circulating pump water piston indicates that the pump is overloaded. See that the air checks at the end of the water cylinder are working, and, if so, open the regurgitating valve or partly shut down the injection or slow the pump.

A thump in the air pump may be caused by one or more valves being carried away. If this is the case there will probably be a fall of vacuum at the same time.

It is a very difficult matter to discover from which direction a sound comes, owing probably to the reflection of the sound waves as they strike different surfaces of the machinery and bulkheads, and also to the metal being a better conductor than air. An illustration of this is a case where search was made in the rigging for the cause of a sound due to vibration of the main injection valve in the bottom of the ship. The true location was discovered by observing that it did not coincide with the rolling of the ship but was exactly coincident with the motion of the independent circulating pump.

If brass cuttings are seen to come from the pipe which lets sea water circulate in the stern tube and enter the bilge, it shows that the lignum vitae strips have worn down to the brass; the propeller shaft is consequently out of line and liable to break at any time.

In order to be able to judge quickly and correctly the cause of any irregularity in the working of an engine it is important to have a thorough knowledge of all the details of its construction and present state of adjustment.

Routine at Sea.

Upon coming on watch, see that the speed of the engines, position of the throttle and cut-off valves is correct, and that all steam and vacuum gauges, thermometers, etc., give normal indications in accordance with a table made out from previous experience.

See that all journals, slides, piston rods, valve stems, etc., are properly lubricated, water in bilge and feed tank not too high and that bilge strainers are clear. Each man informs his relief

of all orders relating to that part of the machinery under his immediate care. The machinist should read up the logs of the two preceding watches to see if anything unusual has occurred, in case his predecessor should have forgotten to mention it. The machinist is principally occupied in observing the movements of the engine as a whole, receiving and making reports, regulating the speed, and noting data in the log. The oilers should keep moving about that part of the machinery under their care, making systematic inspection of all bolts, nuts, keys, set screws, stuffing boxes, and pipe joints, to see if they require tightening, also to keep a lookout for any indications of faulty lubrication, or heating of slides or journals, applying proper remedies when possible and, if not, reporting the fact to the machinist in charge.

The oilers must also, at regular intervals, inspect the bilge strainers and gauge glasses on separators and feed tanks, drain the separators when necessary and notify the water tender if the feed tanks are too full. If the tanks are nearly empty he fills them by salt feed, previously consulting the water tender and machinist with regard to the necessity.

The machinery on other decks, including steering engine, are often cared for by one of the engine-room oilers.

An easy method of cleaning bilge strainers is to use a jet of steam. The usual method is to put the strainer in an ash pit and let the heat melt off the grease.

The oilers must keep the hand rails and engine wiped off, ladders and platforms swept, and see that everything about the engine room is at all times secured for sea, collect data for the log and give it to the machinist at the end of every hour. He must taste the water in the hot well occasionally. If found brackish, it is an indication that the hot well relief valve is stuck open or that the condenser tubes leak. A slight leak in two or three tubes of a condenser which is taking all the steam from a 300 H. P. engine will cause a brackish taste that will be distinctly perceptible.

All use of oil in the cylinders must be avoided; a small quantity of cylinder oil being applied on the piston rods occasionally, if no oil pipe is fitted to the packing box.

The number of wicks in a cup should be increased or diminished as occasion requires and sight feed oil cups adjusted. The wicks should be taken out, dipped in oil, and replaced from time

to time; those that have become clogged with impurities in the oil or soaked with water are to be renewed, taking care not to let them get twisted or extend down far enough to touch the journal. Oil which accumulates in drip pans, under journals and eccentrics, must be removed before it runs over.

Upon entering a shallow, muddy harbor or river, see that no sand enters the water service pipes and gets on the journals.

Changing Speed at Sea.

When manœuvring with a fleet, keep the cut-offs well run out; be ready to let live steam into the receivers at any moment. If required to increase the speed, open out the throttle (or run out the cut-off further) as quickly as possible without causing the index of the steam gauge to tremble. Keep the water tender informed as far as possible in advance of all proposed changes. If the change is to be permanent (to last four or more hours) notify the oilers to regulate the supply of oil. After the cut-offs, pressure, etc., are altered take a set of indicator cards.

Coming into Port.

Upon receiving notice that the ship will come to anchor at a given time, pass the word to the water tender, and also call down whatever part of the relief watch that is needed to bring the ship to anchor; and get the capstan, winch, and steam launch engines ready. Make an inspection of all machinery in operation to see if the reports that have been made during the run, of repairs required, are correct and complete.

As soon as the engines are slowed, shut water off all journals and run the cut-offs out if necessary for quick handling of the engines.

Arrival in Port.

Upon receiving word that the engines will no longer be required, notify the water tender, put the engines in the position most convenient for the work that is to be done first, to save trouble of using turning engines; shut the engine stop valves; open drains on cylinders and valve chests; take out wicks; empty and clean oil cups, scalding the latter with hot water and a little soda; wash out all oil ways in crank pin journals with hot water

and syringe, then oil the journals; clear all oil cups and pipes about engine; stop all oil pipes and cups with plugs of waste if they are not otherwise covered; cover the ends of journals with gaskets and also the piston rods, pump rods, and valve stems, where they enter the stuffing boxes. Set up on the stern tube stuffing box gland. Clean the engine frame and moving parts while the grease is still hot and soft. The air and circulating pumps should be slowed down, but not stopped until the steam pressure in the fire room has fallen and is well under control. As soon as the pumps can be stopped, shut the outboard valves. If the distiller is not in use, start it up to make use of the steam in the main boilers.

When cool remove the man-hole plates from the cylinders, and covers or sight hole plates from valve chests. Inspect the interior for marks of cutting, see if follower bolts, piston nuts, are loose, etc.

The interior of a cylinder should have a good polish all over. If there is a dark streak in a longitudinal direction it indicates that the springs are not tight at that part of the piston. The tightness of a piston may be tested by closing one end of the cylinder, putting the link in mid position and working the engine with the turning engine. A candle on the end of a stick being moved around the circumference of the piston will show by the flickering flame whether much air leaks past as the piston approaches the closed end of the cylinder. If the cylinder is closed at both ends the desired information is obtained by observing the amount of air pumped in and out the indicator pipes.

After inspection, oil the interior of the cylinder and wearing surface of valve chests with cylinder oil and replace the plates, taking notice that the openings of the relief valves are not choked.

Proceed with the repairs found necessary during the run, beginning with the most important and arranging the work so that the different gangs of men will not interfere with each other; that steam will not be shut off the auxiliary pipe by one set, just when it is wanted by another; that floor plates will not be taken up in a passageway where there will be much passing and many other like considerations. Repack all boxes needing it.

In case there are no repairs, proceed with the routine inspections of various parts of the machinery as required by the instructions given in the back of the Steam Log Book. Also clean out

the feed tank and scale evaporators when necessary. Leaky condenser tubes are located by filling the steam space with water after having removed the bonnets over the ends of the tubes. Grease may be melted off the condenser tubes by letting in steam after draining the condenser, taking care not to get up a pressure in the condenser. If this does not succeed, fill the steam space with a solution of lye, soda or potash in fresh water and boil by admitting a jet of steam in the bottom. If the flat rubber valves used in many air pumps are curled up, they must be turned, trimming the edges if found to have swelled and overlapped the valve seat too far. If soft, the valves must be renewed.

It is customary to devote the morning watch to cleaning bright work, working all levers, valves, cut-off gear, etc., about the department. Iron and steel are cleaned with emery cloth and oil, taking care to rub in the direction in which the piece was finished by the manufacturer, that is for a lever of flat section rub the flat sides in a longitudinal direction and the round handle in a plane perpendicular to the axis. After polishing, such pieces are wiped with an oily rag to leave a very thin film of oil on the surface. Brass is polished with Putz pomade or else with finely ground bath brick sifted through bunting. Use woolen rags for the final polish and leave the brass as dry as possible. Soiled spots on the paint work are removed by washing with soap and water or with turpentine on a rag. Parts of the engine frames and bulkheads where the paint is blistered or peeled are washed with lye or turpentine and repainted. Bulkheads and other paint work are scrubbed with soap and water. Ladders and floor plates are scraped, washed with lye, dried and blackened with plumbago rubbed on with a brush, using very little plumbago and rubbing a great deal or, by giving a coat of asphaltum varnish. Hot, dry ashes will remove grease from floor plates. Wooden lagging is scraped and rubbed off with boiled linseed oil and a rag.

The main engines must be oiled and moved about one turn of the crank every day, taking care that the links are in full gear at the time so that the main valves will be moved also.

Auxiliary engines must be turned every day and be worked periodically as often as found necessary by experience: those on the upper decks must be kept well drained and covered up in cold weather if there is danger of freezing. The engine room bilges

must be cleaned within a day or two after reaching port and once a week after that. Oil can be most readily removed from the bilges by using scalding water from the boilers. If cold water is used, caustic potash, or better, soda, must be mixed with it to form a strong lye which is applied with a swab. All thick deposits must first have been scraped away and taken up.

Disinfectants are not to be used instead of cleaning, but in addition to it. The following disinfectants are used: The best is that prescribed July 11, 1883, by the German Government for use on all merchant vessels, viz. hydrargyrum bichloratum=bichloride of mercury=corrosive sublimate. One pound is dissolved in twenty pounds of water and enough of this solution used so that there shall be one pound of the sublimate to every half ton of bilge water. In a pulverized form it costs about one dollar per pound but, as it is much more diluted for use than any other disinfectant, the final cost will not be much, if any, greater. It is a deadly poison and must not be tasted nor allowed to get in a cut or sore. Another disinfectant is required to be used in the German navy, viz. chloride of zinc used in a diluted state. It is not so efficacious as the sublimate. It costs about fifty cents per pound. Nitrate of lead in powdered crystals costs about twenty-five cents per pound and is very efficacious. It should be diluted as the others, for a disinfectant. When diluted sufficiently for the purpose for which it is used, it has no effect whatever in the way of corroding iron as may easily be proved by trying a sample. A piece of bright iron remained bright several months when immersed in such a solution. The two latter as well as the first are deadly poison when taken internally or absorbed through cuts or sores, and must be handled accordingly.

After the bilges, come the double bottom compartments, observing the same precautions prescribed in the case of those in the fire room. While in port a fair share of time should be devoted to keeping spare parts of machinery, tools, etc., in good condition.

Ship in Dry Dock.

Under these circumstances, the first work to be done is the inspecting, overhauling and repacking of all sea valves and clearing their strainers, renewing zinc protectors, etc., taking care to not remove more valves in a day than can be replaced before

night, as required by the regulations. Also inspect the interior of the pipes as far as possible while the sea valves are removed, and note any pitting or deterioration of the pipes.

Inspect the propellers and see that all bolts are tight. Get an accurate measure of the space between the top of the shaft and the top of the stern bearing to determine how much the bearings have worn down and record it in the log. Remove the shaft coupling bolts of the coupling nearest the engine and the packing from stern tube stuffing box, attach a lever to a blade of the propeller, then suspend weights on the end until the shaft turns. Make a record of the weights and length of lever. By comparing such records, any increase of friction due to the shaft being out of line or other causes will be discovered. The packing in the stern tube stuffing box must always be inspected by removing a few turns and judging from them whether the whole amount needs renewal.

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